

The Deep Space Network's X/X/Ka Feed: Modifications for 100 kW CW Uplink Operation

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Introduction

The Deep Space Network, which provides communication services for NASA's robotic missions, consists of a number of 34m beam waveguide antennas and conventional 70m dual-reflector antennas located around the globe, [1]. The 34m beam waveguide antennas employ a three-band feed covering the deep space uplink band near 7.2 GHz, and downlink bands at 8.45 and 32 GHz. Simultaneous uplink commanding at 25 kW CW and ultra low noise reception in both bands is supported along with monopulse tracking at 32 GHz, [2]. An existing uplink capability of 25 kW is also available on the 70m antennas using a more conventional X/X diplexing feed. In order to provide an equivalent uplink capability with the 34m antennas the X/X/Ka feed is currently being modified for 100 kW CW operation, [3]. Here we will discuss both the existing feed and the 100 kW modifications which are underway.

System Description

As depicted in Figure 1, the feed employs a turnstile junction, fed through a 3 dB hybrid and magic tees for simultaneous X-band (8.45 GHz) downlink reception in both polarizations. Both polarizations are also received at Ka-band (32 GHz) through a conventional fin polarizer. In addition, a singly polarized tracking signal is available through a TE₂₁ monopulse tracking coupler. All of the receive components are housed inside a 4K helium cooled cryostat. As part of the high power upgrade the uplink hybrid and splitters will be replaced with a high power 8 port super-hybrid of the type described in [4]. As configured here the super-hybrid presents LCP and RCP input ports and four properly balanced 25 kW signals for the uplink turnstile. Harmonic power from the saturated 100 kW klystron amplifier must be contained in order to meet spurious radiation requirements. In addition, the fourth and fifth harmonics can enter the Ka-band receive system and increase system noise temperature. Depending on the harmonic, between 60 and 100 dB of attenuation is provided by a 100 kW absorptive filter and separate 25 kW waffle iron reflective filters in each arm feeding the turnstile. Two sets of narrow band filters are also included to decouple the low noise X-band receive system from the uplink transmitter. The uplink beam noise filter provides approximately 100 dB of isolation between the 7.2 and 8.45 GHz bands. In addition, a second 30 dB filter is located in close proximity to the turnstile junction, fixing the effective short position for the turnstile at 8.45

GHz. As part of this high power upgrade the existing 25 kW waffle iron and beam noise filters are employed, but moved into the for turnstile arms. Careful phase matching of all of components in these arms is required across the small uplink band in order reduce reflection and preserve uplink polarization purity.

Feed Design Details

Figure 2 depicts the original prototype feed photo including the receive and transmit junctions and the thermal break, but excludes the large output horn sections. In this effort the existing single-slot uplink turnstile has been replaced with the 100 kW junction shown in Figure 3. Here two non-adjacent corrugations are fed with a total of 25 kW. This configuration allows for efficient water cooling of the reduced height sections. In addition, the 30 dB bandpass filter is implemented with thick irises as shown. Ka-band corrugations are employed through the uplink turnstile, and then are transitioned to X-band corrugations using a single matching slot later in the feed. A thin Kapton window located below the thermal break provides the vacuum barrier. Both turnstile diameters are chosen so that they propagate only a single mode at their operating frequency. The tapered corrugated section between the two X-band junctions provides the back-short for the uplink turnstile and isolates the high power uplink from the cryogenic LNAs. All uplink sections of the feed are liquid cooled, and non-vacuum portions of the feed are vented with dry nitrogen during operation. The output diameter and flare angle of the horn are chosen to provide nearly identical beamwidth in all bands, using saturated operation at Ka-band.

Testing

The return loss due to the new uplink junction was measured as better than 30 dB across the 31.8-32.3 GHz downlink band, 20 dB in the deep space downlink band from 8.40-8.45 GHz, and 25 dB in the primary deep space uplink band from 7.145-7.190 GHz. Radiation patterns in all three bands were also measured using a near field antenna range. Excellent pattern symmetry was achieved in all bands, despite the Ka-band signal traversing two X-band turnstile junctions. The high power capability of the feed arms, including the junction filters, two-way splitter, and matching irises was also verified. This was accomplished by fabricating an additional iris section to simulate the turnstile mismatch and placing it between the two arms in a back-to-back configuration. An existing 20 kW uplink transmitter was used to drive the arms. Arc detection systems and infrared cameras were used to monitor the tests. No arcs or excessive heating were observed for operation up to the output power limit of the transmitter, 21 kW. Further high power testing will await delivery of the new 100 kW amplifier.

Future Plans

Upon the successful completion of the low power test program and high power feed arm tests described here fabrication of high power electroformed components

was initiated. Assembly of a complete cryostat and low noise receiver system is also underway. These components will then be integrated with the first 100 kW amplifier which is due to be delivered in mid/late 2010. High power diplexing tests will then be conducted in order to verify ultra low noise PIM-free operation in the presence of the 100 kW uplink.

Acknowledgement

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References

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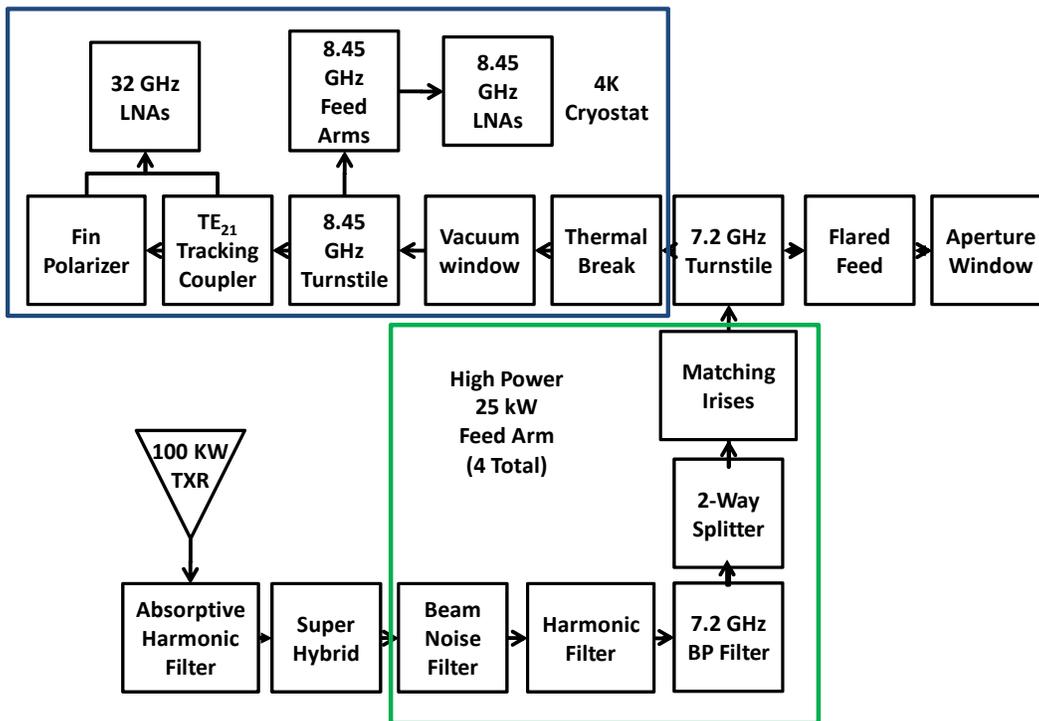


Figure 1X/X/Ka feed system block diagram.

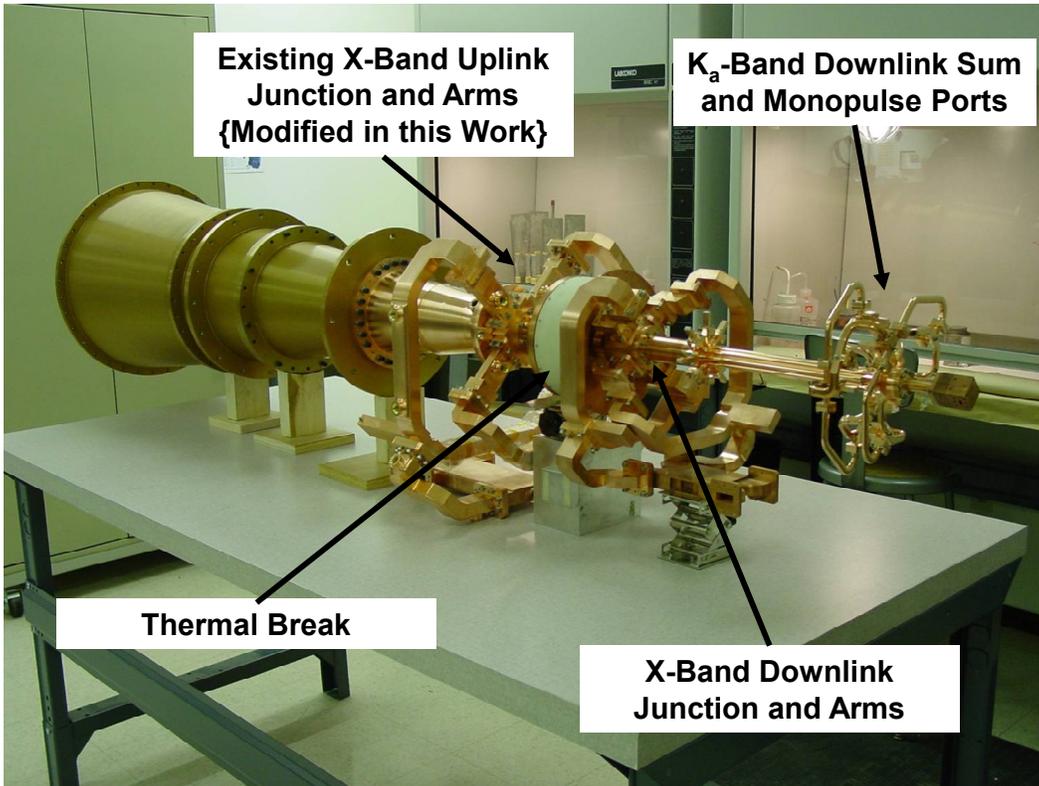


Figure 2 Input section of the prototype feed.

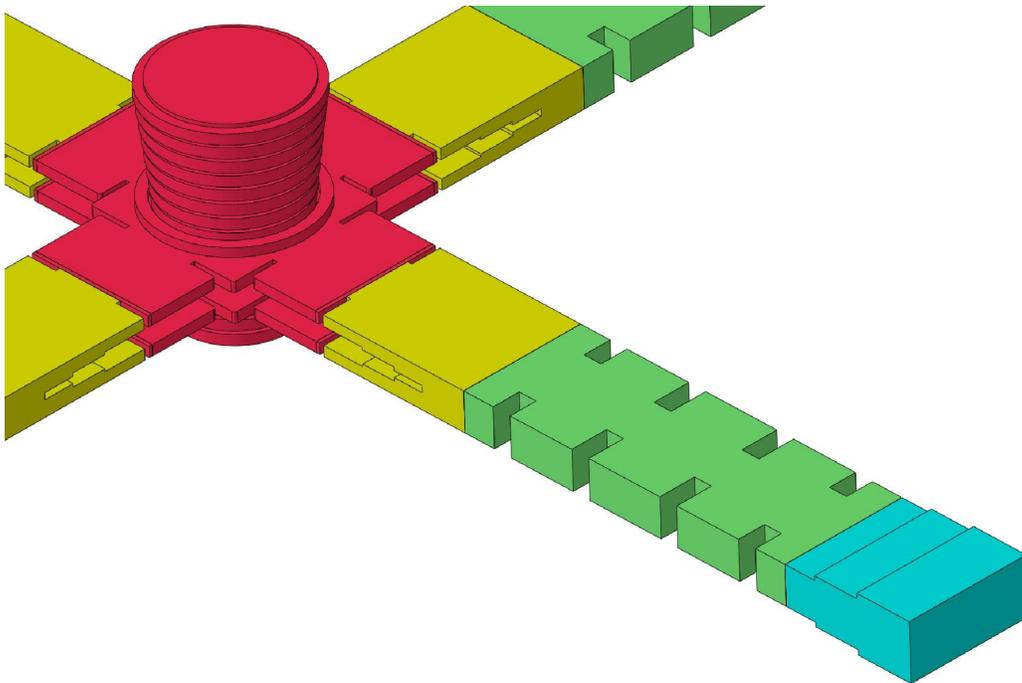


Figure 3 100 kW dual-slot turnstile junction.