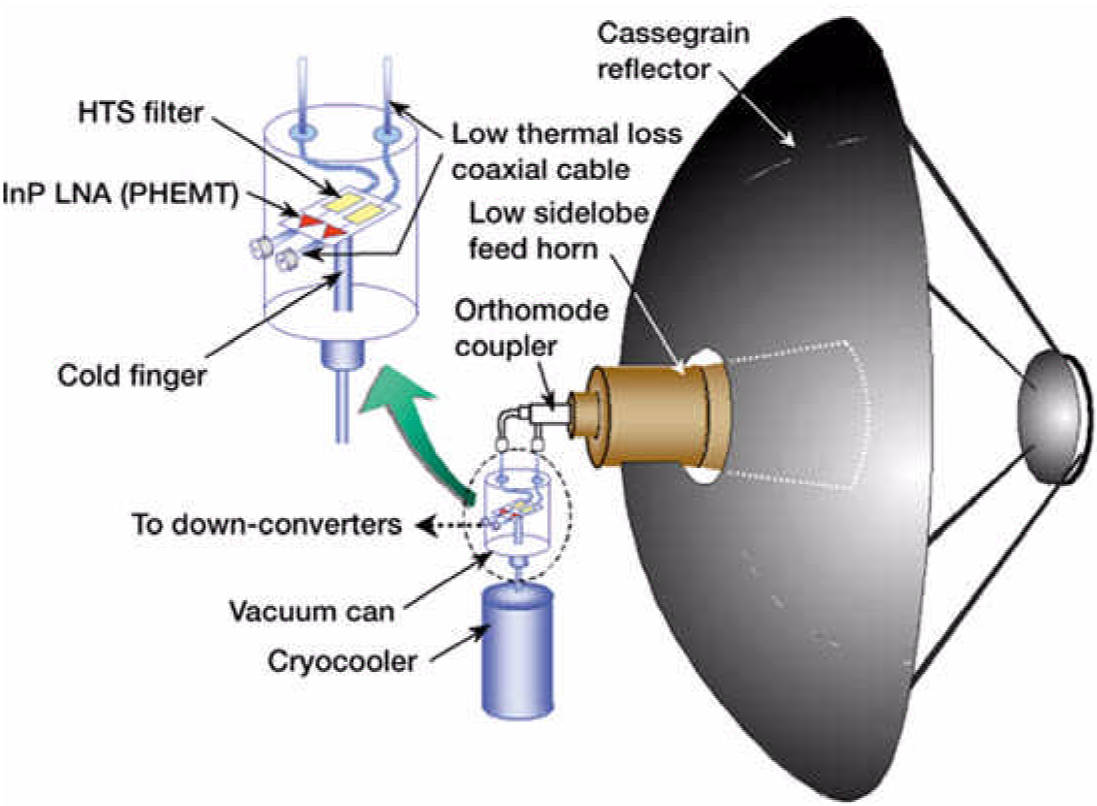
Low-Cost Tracking Ground Terminal Designed to Use Cryogenically Cooled Electronics

A computer-controlled, tracking ground terminal will be assembled at the NASA Glenn Research Center at Lewis Field to receive signals transmitted by the Glenn's Direct Data Distribution (D^3) payload planned for a shuttle flight in low Earth orbit. The terminal will enable direct data reception of up to two 622-megabits-per-second (Mbps) beams from the space-based, K-band (19.05-GHz) transmitting array at an end-user bit error rate of up to 10^{-12}. The ground terminal will include a 0.9-m-diameter receive-only Cassegrain reflector antenna with a corrugated feed horn incorporating a dual circularly polarized, K-band feed assembly mounted on a multiaxis, gimbaled tracking pedestal as well as electronics to receive the downlink signals. The tracking system will acquire and automatically track the shuttle through the sky for all elevations greater than 20° above the horizon. The receiving electronics for the ground terminal consist of a six-pole microstrip bandpass filter, a three-stage monolithic microwave integrated circuit (MMIC) amplifier, and a Stirling cycle cryocooler (1 W at 80 K). The Sterling cycle cryocooler cools the front end of the receiver, also known as the low-noise amplifier (LNA), to about 77 K. Cryocooling the LNA significantly increases receiver performance, which is necessary so that it can use the antenna, which has an aperture of only 0.9 m. The following drawing illustrates the cryoterminal.



Cryogenic receiver terminal for the Direct Data Distribution project. (HTS, high-temperature superconducting; PHEMT, Pseudomorphic High Electron Mobility Transistor.)

A three-stage indium-phosphide (InP) MMIC low-noise amplifier (LNA) was designed to provide the flexibility for both broadband operation and high gain. Source feedback was used in the first-stage device to provide good noise match and input voltage standing wave ratio (VSWR) match simultaneously. The advantages of an InP High Electron Mobility Transistor (HEMT) over gallium arsenide (GaAs) devices include higher gain, lower power consumption, and a lower noise figure, especially at cryogenic temperatures. The MMIC LNA is fully monolithic and has exhibited good reliability with median time to failure of 10^8 hours. The LNA gives a noise figure of 1.1 dB with 33 dB gain at 20 GHz at room temperature. From 17 to 22 GHz, input and output return losses greater than 10 dB can be achieved with an MMIC amplifier. Under normal operation, the amplifier can take input power up to 20 dBm without any degradation. When biased for minimum noise at 19.0 GHz, the minimum noise at 299 K was 1.6 dB with an associated gain of 27 dB. At 82 K, the minimum noise was within the measurement uncertainty of the system, estimated at 0.2 dB, and the associated gain was 27 dB.

Because of the high gain and wide bandwidth of the LNA, a high-temperature superconductor edge-coupled microstrip band-pass preselect filter is used ahead of the LNA. This prevents the LNA from being driven into saturation by powerful out-of-band sources, and it reduces interference. The filters were designed on 250-µm-thick $LaAlO_3$

and 300-μm-thick MgO. For each filter, a six-pole design was chosen as a compromise between insertion loss and rolloff. The inband insertion loss of the filter on the $LaAlO_3$ and MgO substrates is 0.9 and 0.6 dB, respectively. The final selection between the $LaAlO_3$ and the MgO filter will be based on further measured performance.

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