# Exhibit
# Antenna Registration Question 4: Directional Antenna Information
# ANTENNA DESCRIPTION
## Morehead State University 21 M Space Tracking Antenna

**ANTENNA DESCRIPTION:**

The Morehead State University 21 m Space Tracking antenna is a full-motion, directional, parabolic antenna. The antenna system is located above the campus of Morehead State University in Morehead, KY, USA. The antenna is oriented with an azimuth axis of 0 degrees oriented due North. Basic performance parameters and RF performance characteristics are provided below.

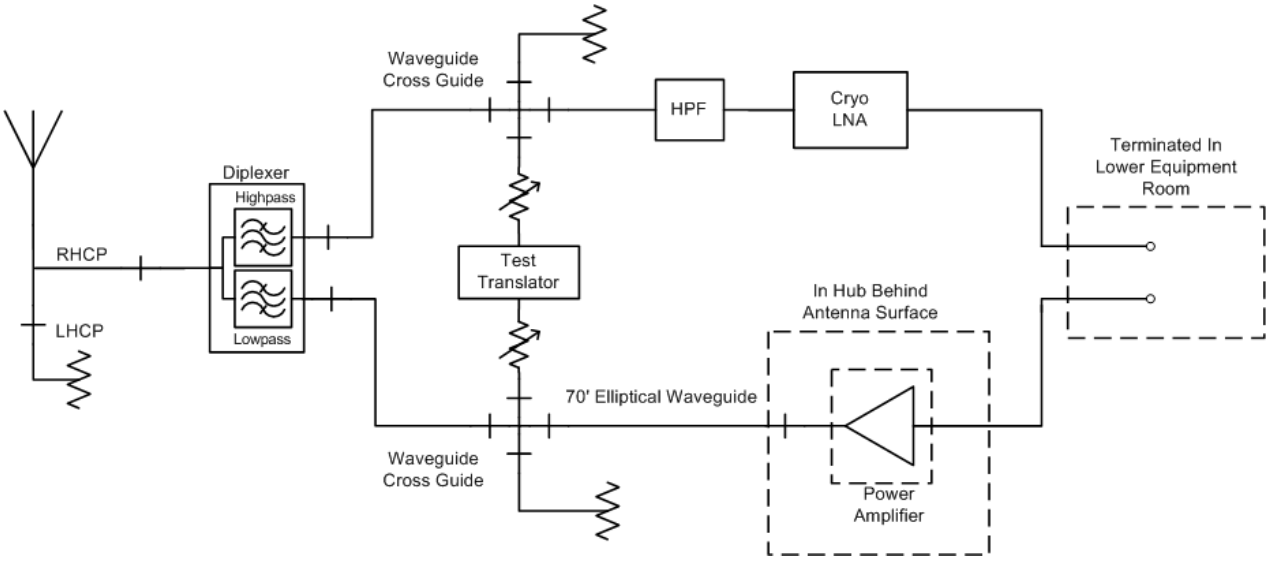
| FUNCTION | PERFORMANCE |
|---|---|
| **Antenna Diameter** | 21 Meter |
| **Receive Polarization** | RHCP,LHCP,VERT,HORZ |
| **Travel Range** | AZ +/- 275 degrees from due South (180 deg)<br>EL -1 to 91 degrees<br>POL +/- 90 degrees |
| **Velocity** | AZ Axis = 3 deg/sec<br>EL Axis = 3 deg/sec<br>POL Axis = 1 deg/sec |
| **Acceleration** | AZ = 1. 0 deg/sec/sec min<br>EL = 0.5 deg/sec/sec min |
| **Display Resolution** | AZ/EL = 0.001 deg<br>POL = 0.01 deg |
| **Encoder Resolution** | AZ/EL = 0.0003 deg (20 Bit) |
| **Tracking Accuracy** | <= 5% Received 3 dB Beamwidth<br>(0.028 deg RMS L-band)<br>(0.005 deg RMS Ku-Band) |
| **Pointing Accuracy** | <= 0.01 deg rms |

| Performance Measure | Performance Value |
|---|---|
| **X-Band Frequency Range*** | 7.0 – 8.5 GHz |
| **X-band Uplink Range*** | 7.145 – 7.235 GHz |
| **X-band Downlink Range*** | 8.400 – 8.500 GHz |
| **LNA Temperature** | < 20 K |
| **System Temperature $T_{sys}$** | <100 K |
| **Antenna Gain** | 62.7 dBi (@8.4 GHz) |
| **System Noise Spectral Density** | <-178 dBm/Hz |
| **G/T at 5° Elevation** | 40.4 dBi/K |
| **Time Standard** | H- MASER (1ns/day) |
| **EIRP** | 93.7 dBW |
| **HPBW** | 0.1150 deg |
| **SLE Compliant** | Yes |
| **CCSDS Capable** | Yes |
| **Forward Error Coding** | Reed Solomon/Convolutional, Turbo, Low Density Parity Check |
| **Radiometric** | Angle, Doppler, Sequential Tone and PN Ranging |
| **Ranging Precision** | +/-1 range unit (0.94 ns) |

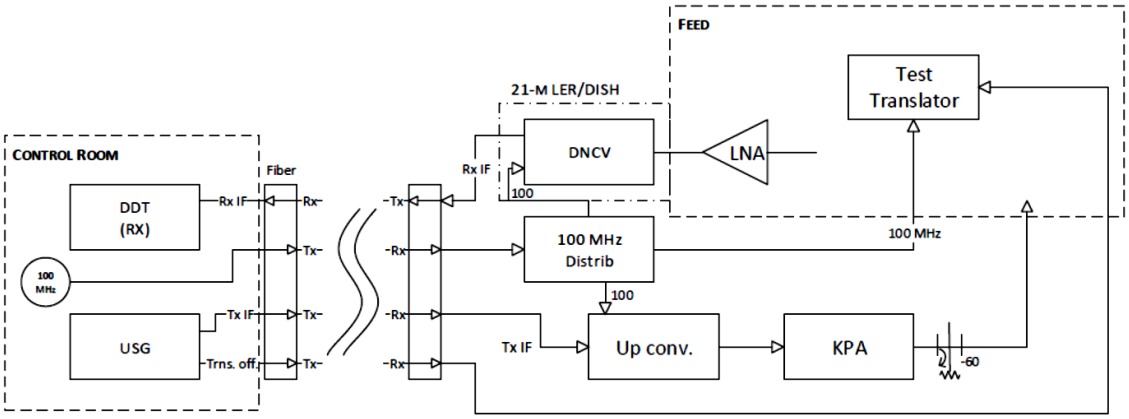
*Photograph of the Morehead State University Space Science Center 21 Meter Space Tracking Antenna September, 2020*

RECEIVER/TRANSMITTER DESCRIPTION:

The 21 m station's current S- band configuration supports operations as an independent station offering direct connection from the mission's operation center (MOC) to the 21 m Station Operations Center (SOC). TheX-band system is primarily used for LEO mission support (uplink and downlink and ranging). A block diagram of the standard 21-m feed configuration is shown below, followed by the overall systems architecture. The X-band feed consists of a horn, coupler, orthomode transducer (OMT), low noise amplifier (LNA), and noise control source or test inject system. Down conversions are accomplished using frequency-specific, interchangeable tuners.

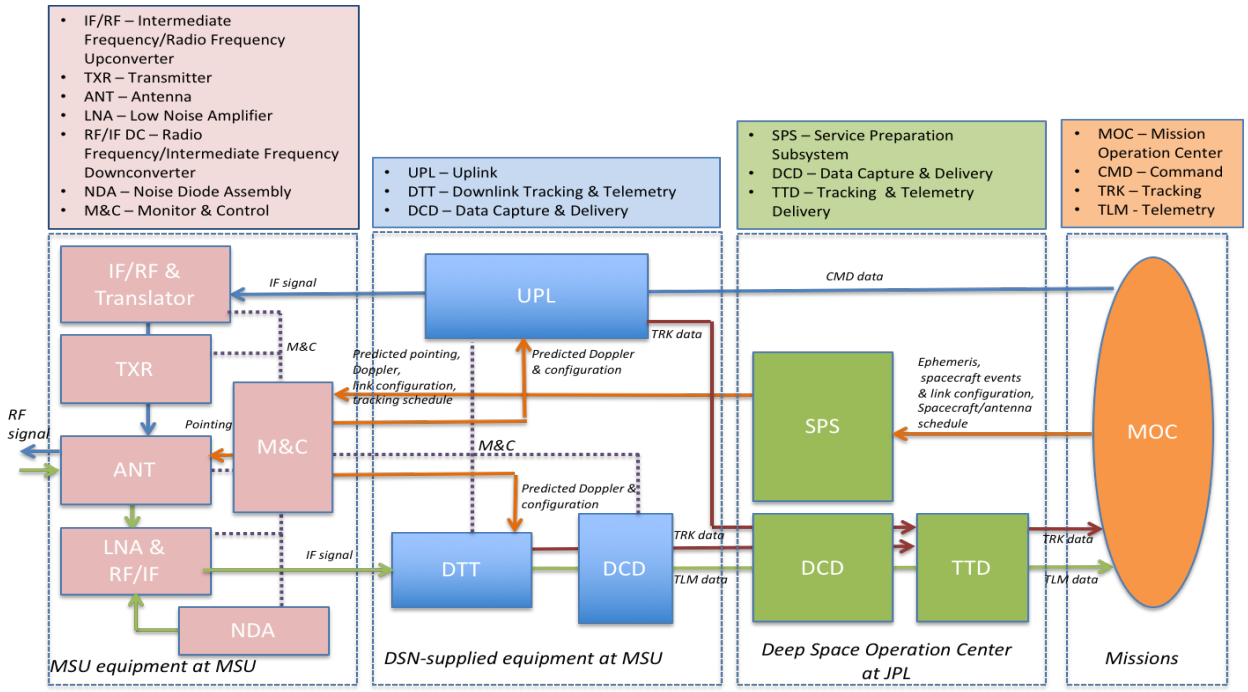



*Block Diagram of the 21 m X-band Feed*




RF System Block Diagram

The 21-m receiver system incorporates back-end (digital front-end) technologies that includes complete automation and control systems (for remote autonomous operation of the 21 m) and a NASA Deep Space Network Block 6 Receiver and signal generator (shown below).




*Block Diagram of the 21 meter Antenna DSN Block 6 Receiver/Transmitter System*

The 21 -m transmitter system incorporates a 3 KW CPI GEN IV Klystron Power Amplifier (KPA) is utilized for the uplink. Basic information describing the KPA system is shown below.

K4C75LBNZ0F00EF, 2.45KW, 6.7-7.3 GHz Gen IV Klystron High Power Amplifier Outdoor with a VKC2505D-M24 Klystron.

- CPI GEN IV Klystron PA
- Frequency Range 7.9 - 8.4 GHz
- Klystron Power Output 3.0 kW min. (64.77 dBm)
- Gain at 3 KW = 77 dB, min.
- Gain Stability vs. Time ±0.25 dB/24 hr. max. at constant drive and temperature
- Noise and Spurious = -65 dBW/4 kHz, 4.2 - 12.0 GHz
- Bandwidth = 40 MHz