Experimental License Application
Cornell University Space Systems Design Studio
Form 442 Question 6: Description of Research Project
File Number 0395-EX-PL-2013
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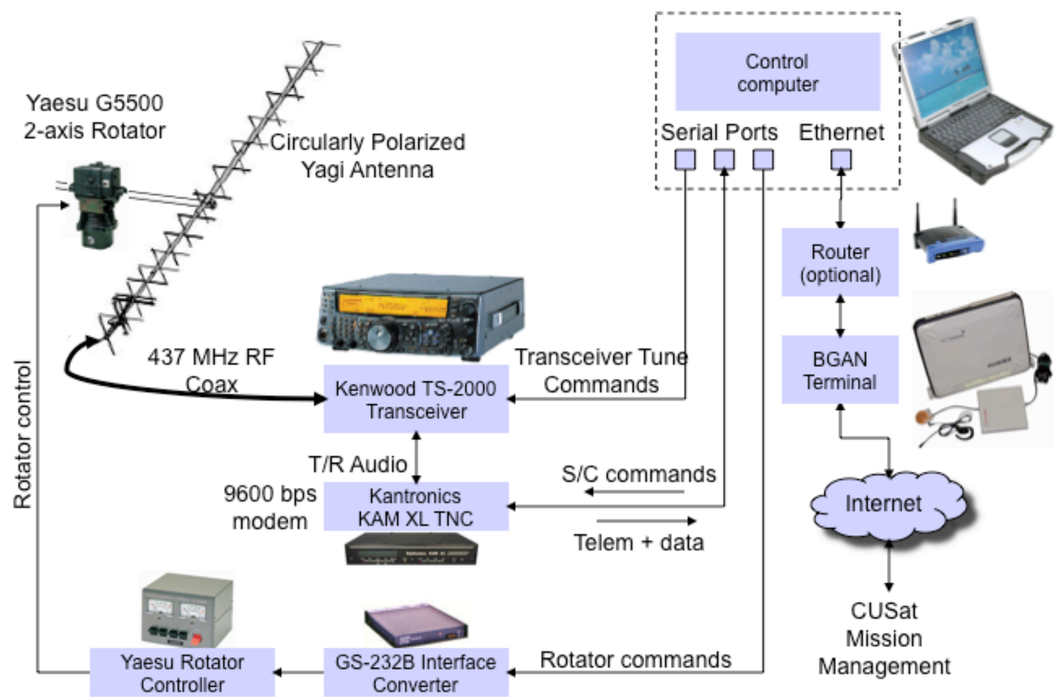
a. The research project which requires the communications capabilities outlined below is CUSat, of Cornell University. CUSat is the winner of the University Nanosat-4 Program. CUSat is a multi-year effort to design, build, and launch an autonomous in-orbit inspection satellite system. The original CUSat space vehicle consisted of two functionally identical satellites that would launch together and separate in orbit. Using centimeter accuracy carrier-phase differential GPS, the two satellites will perform autonomous relative navigation. Due to hardware malfunctions, CUSat will now launch only one satellite, but still focus on the verification and testing of carrier-phase differential GPS technology as well as attitude determination algorithms.

b. In order to communicate with CUSat while it is in space, the CUSat team determined an optimal design for our ground station, outlined below. All of the equipment is necessary to ensure successful and safe communication with the satellite.



The antenna structure is one of the most important components in the ground station. Paired with a transceiver, it can single-handedly determine whether a radio connection to the satellite will be successful or not. An antenna also requires a rotator in order to correctly orient itself and point at the satellite. An incorrectly pointed satellite will have degraded quality of signal.

The antenna in use is an M2 436CP30 70cm circularly polarized antenna. It has 14.5 dBc of gain and about 9 feet and 9 inches long. The antenna itself is mounted on a pipe that is mounted in the rotator, while the whole antenna structure can be mounted on or clamped to any reasonable fixed structure.

The G-5500 rotator includes the rotator motors that the antenna is mounted on and the rotator switch box controller. The rotator turns the antenna towards the desired azimuth and elevation levels. The rotator control box has simple up/down and left/right switches for controlling the rotator and a simple analog read-out of the current antenna position. The analog read-out must be configured prior to use to ensure accurate read-outs. The configuration could be as simple turning the antenna rotator all the way to the left until it hits a hard stop, marking that as the zero point, and then turning the antenna in the other direction to mark the next hard stop as a 450º point. Similar steps can be achieved for configuring the elevation levels from 0º to 180º.

The TS-2000 is the main transceiver and is used for sending radio signals to and from the satellites. It is capable of transmitting on many amateur radio bands, including the 70cm amateur radio band that CUSat is interested in. For the 70cm band, the TS-2000 is also capable of transmitting at 50 W of power, which fulfills the transmission power subsystem requirement

A TNC, or Terminal Node Controller, is required for data packet operation over amateur radio. The function of a TNC is to convert digital packet data into analog sounds that can be transmitted and received. It may be useful to think of a TNC as a similar device to a computer modem, except a modem does its tasks over phone lines instead of amateur radio. Although the TS-2000 includes its own TNC function, it only has one serial port. This one serial port will normally be connected to the computer so that the computer can automatically tune the radio, which means that it would not be possible to use both TNC and radio tuning functions at the same time. The original design plan was to use the built-in TNC, but this characteristic was not compatible with the required CUSat interfaces. As a result, a dedicated, separate TNC is needed in order to encode the packet data.

The pre-amplifier serves to amplify signals so they are stronger and more easily picked up by the transceiver. The ground station currently uses a mast-mounted GaAsFET pre-amplifier designed for 70cm amateur radio band from SSB Electronic USA. The pre-amplifier fits in-between the antenna and the TS-2000 transceiver, but is physically much closer to the antenna in the system. The reasoning for this is to minimize cable losses and to place the pre-amp closest to where it can make the most difference. The pre-amplifier is specified to provide up to 20 dB of gain, though it is user-selectable on a range from 10 dB to 20 dB.

The following communication examples show how all these components will be used together during the CUSat mission.

The following is an example sequence of events involved in downlinking telemetry from a satellite.

- The signal transmitted by the satellite is received by the ground antenna, amplified by the receiver front-end and then detected by the TS-2000 transceiver. The radio signal is unencrypted on the 70cm amateur radio band, and is analog as radio transmissions are inherently analog.
- The transceiver then sends the signal via RS232 serial communication to the KAM-XL TNC, which will digitize the received signal. This digitized information is sent via another RS232 serial cable to a nearby computer equipped with a Radio Gateway, which forwards the received packets over TCP/IP to the InControl Server.
- IP packets, encapsulating GSL packets, are routed over the Internet through a secure Virtual Private Network connection to the Mission Control Center in Ithaca, NY.
- The data is received by an InControl Gateway, which is then decommutated and assembled by the InControl Server into the internal parameter database. The data is displayed to ground station operators using the InControl client software on analyst stations.

The following is an example sequence of events involved in uplinking a command to a satellite.

- The ground station operator in the Mission Control Center uses the InControl client on an analyst station with the control token to issue commands to the Space Segment. InControl processes these commands into proper GSL packets.
- Command data is then packetized for routing over the Internet, and then sent through a secure Virtual Private Network connection to the appropriate ground station.
- Gateway Software at the ground station computer receives TCP packets, extracts the relevant GSL packet, and sends it to the KAM-XL TNC, which then sends it to the TS-2000 transceiver.
- The transceiver then transmits the data to Space Segment through the RF front-end and antenna. This radio signal is also unencrypted on the 70 cm amateur radio band.

c. In accordance with our design which won the University Nanosat IV competition run by the Air Force Office of Scientific Research, successful completion of the CUSat mission hinges upon safe and effective communication with our satellite. Thus the equipment must be implemented as designed to ensure mission success. Existing communications facilities are inadequate as they do not meet all of CUSat's design requirements.