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Introduction
The Communication Subsystem is one of the vital parts of the CubeSat project. The primary goal of this group is to provide a link to relay data findings and send commands to and from the CubeSat. Telemetry and command subsystems will ensure continuous communication between the ground station and the CubeSat. Analog and digital data collected by the sensors and payload of the satellite must be relayed to the ground station via the telemetry system. A radio operating in the Ultrahigh frequency (UHF) band at the ground station will receive the data signal and encode the stream to a format that may be interpreted by software on a laptop. Another vital aspect of the communication subsystem is the command/uplink portion. From the ground, moderators must be able to send commands to the system. All incoming signals from the ground station will be compared to all other inputs, and any errant signals are discarded. The Satellite Solutions CubeSat design will implement commercially available transmitter and receive packages that operate in UHF, and therefore, care must be taken to ensure that the correct radio-data protocol is followed for the transmission to be efficient, reliable, and robust.

Requirements & Constraints
1. Mass & Volume: The Cubesat specs set strict requirements on mass and volume. These requirements are non-negotiable as they are required for the Cubesat to fit properly within, and launch correctly from inside of, the Cubesat deployer. It must be no larger than 10 cm on each side and weigh less than 1 kg.
2. Transmitter & TNC: Since only a fraction of the 1000 cm³ volume is allotted to communications, the team must select a transmitter and terminal node controller (TNC) that are miniaturized.
3. Budget: The entire system must also be relatively inexpensive and operate within the designated frequency band allowed under the Federal Communications Commission (FCC) amateur radio guidelines.
4. Data Rate: For adequate communication time, the data transmission rate is desired to be at least 9,600 baud, and the amount of working amperage drawn by the communication subsystem must not exceed the available power provided by the batteries or solar cells.
5. Space Environment: The harsh environment of space will do its best to meddle with the inner workings of any satellite. Space presents an extreme environment in both temperature and pressure. We must design our communications subsystem to operate in these extreme conditions and test and quantify its behavior before final launch.
6. Beacon: It was determined that CubeSats with audible beacons are much easier to locate and contact after deployment. An audible beacon is required in addition to an AX.25 beacon in order to help audible acquire the satellite quickly and therefore obtain more usable time from the limited Communication window.

Controlling Parameters
Radio Propagation
Radio waves consist of a system of electric and magnetic fields that travel through space at a velocity of 3 x 10⁸ m/s. For most of their journey the signals that propagate from the satellite in essentially what is free space, traveling without change aside a change in intensity in proportion to 1/r² as the distance r from the source increases. In the last few kilometers, as they pass through the Earth’s atmosphere there are significant effects to the system performance.
- Propagation describes the transmission of radio waves through non-ideal media.
- Atmospheric can cause refraction, absorption and scintillation.

Antenna Gain
Gain (directive) G is ratio of power density with directional antenna to power density with isotropic radiator with same total radiated power. For uniformly illuminated antenna with area A at wavelength λ, G=4πA/λ²

Signal Noise
All electrical systems have noise - ultimately due to random thermal motion of electrons which appear as random voltages and currents. Each resistive element in a circuit generates a thermal noise with a power spectral density.

Link Budget
Energy per bit EB(U), Eb=C/R where R (bps) is the data rate (Phase/frequency shift modulation runs transmitter at max power all the time).

Subsystem Factors
1. Include simple reset in case the satellite becomes non-responsive
2. Verify ground station early
3. Use common amateur modes for data communication
4. Include a long beacon
5. Don’t depend on another ground station to close the communication link

References
2. Course at UT Austin, "Paper Sections Communication Subsystems", Spring 2003
3. CubeSat, Internet: cubesat.wikidot.com

Figure: Ncube-2, a Norwegian CubeSat