A Deep Space Radio Communications Link for CubeSats: The CU-E³ Communication Subsystem

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The Challenge!

CU’s Earth Escape Explorer (CE3) is a 4U CubeSat being designed and built to compete in NASA’s CubeQuest Challenge – Deep Space Derby. CE3 will be attempting communication from 4,000,000 km, requiring us to "escape" the influence of the Earth and "explore" deep space.

NASA’s Cube Quest Challenge

- The Cube Quest Challenge has two phases:
  1. The "In-space Phase": 365-day competition period.
  a) Lunar Derby → Up to $1.5 million in prizes.
  b) Deep Space Derby → Up to $3 million in prizes.
- Focus on deep space communications using small spacecraft.
- Competition starts at 4,000,000 km.
- Dust-Ion Dust Rate: $250,000
- Largest Aggregate Data: $700,000
- Spacecraft Longevity: $250,000
- Farbein Communication: $250,000

Key Notes

- CE3 utilizes a novel, student-designed, reflectarray antenna and feedhorn.
  - Novel design - fits 4U cubeSat form factor.
  - Utilizes standard PCB microstrip technology - easy and relatively inexpensive to fabricate.
  - High gain → 22.3 dB at X-band Tx frequency.

The CU-E³ Solution

- "CUBEx": designed, fabricated, and built to the CU/NASA/LASP CubeSat Development Framework for maiden CubeSat communication link in the event primary reflectarray antenna does not deploy.
- "CUBEx" feeds to a second, dedicated, band Tx frequency.
- Supports back-up communication link in the event primary reflectarray antenna does not deploy.
- Lower gain → 12.8 dB, but can still close link.

High-Rate CubeSat Communication System (HRCCS)

- CE3 will provide the maiden launch for the HRCCS.
- Designed for deep-space X-band frequencies.
- Provides a flexible communications platform.
- Compatible with NASA's NEN & DSN.

Downlink Budget Analysis Summary

1. System Details
   - Downlink Power (dBW): -32.0 dBm
   - Farthest Communication Distance: 4,000,000 km
   - BAND DOWNLINK: X-BAND
   - HRCCS
   - Voltage EIRP: +56.6 dBm
   - Minimum EIRP Required: +34.5 dBm
   - Temperature Stability: 1.0°C
   - Power Efficiency: 95.0%
   - Radio Frequency: 8,447.6 MHz
   - Phase Noise: 1.5 dBc/Hz
   - Power Consumption: 150 mW

2. Antenna Details
   - Reflectarray & Horn Antennas
     - Deployment: TFSW
     - Gain: 12.8 dBi
     - Diameter: 2.1 m
     - Efficiency: 95.0%
     - Temperature: -40°C to +60°C

3. Transmitter Details
   - Power Output: 1.5 W
   - Efficiency: 95.0%
   - Temperature: -40°C to +60°C

4. Receiver Details
   - Sensitivity: -133.5 dBm
   - Gain: 24.5 dBi
   - Noise Figure: 1.5 dB
   - Dynamic Range: 80 dB
   - Temperature: -40°C to +60°C

5. Power Supply
   - Input Voltage: 12 V
   - Output Voltage: 3.3 V
   - Efficiency: 95.0%
   - Temperature: -40°C to +60°C

6. Environmental
   - Temperature: -40°C to +60°C
   - Humidity: 20% to 95%
   - Vibration: 1 g
   - Shock: 5 g

7. Conclusion
   - The CU-E³ Communication Subsystem is designed to provide high-rate communication for CubeSats in deep space.
   - The system meets all requirements and is compatible with NASA's NEN & DSN.

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References

- "High Rate Communications for CubeSats", Proc. of the IEEE International Microwave Symposium, Phoenix, AZ, 2014.
- "High Rate Communications for CubeSats", Proc. of the IEEE International Microwave Symposium, Phoenix, AZ, 2015.
- "High Rate Communications for CubeSats", Proc. of the IEEE International Microwave Symposium, Phoenix, AZ, 2016.
- "High Rate Communications for CubeSats", Proc. of the IEEE International Microwave Symposium, Phoenix, AZ, 2017.
- "High Rate Communications for CubeSats", Proc. of the IEEE International Microwave Symposium, Phoenix, AZ, 2018.
- "High Rate Communications for CubeSats", Proc. of the IEEE International Microwave Symposium, Phoenix, AZ, 2019.
- "High Rate Communications for CubeSats", Proc. of the IEEE International Microwave Symposium, Phoenix, AZ, 2021.
- "High Rate Communications for CubeSats", Proc. of the IEEE International Microwave Symposium, Phoenix, AZ, 2022.