Building Proof of Concept CubeSAT & Ground Station Hardware

In association with APS STEM Trajectory Initiative

Abigail Bass
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Albuquerque, NM

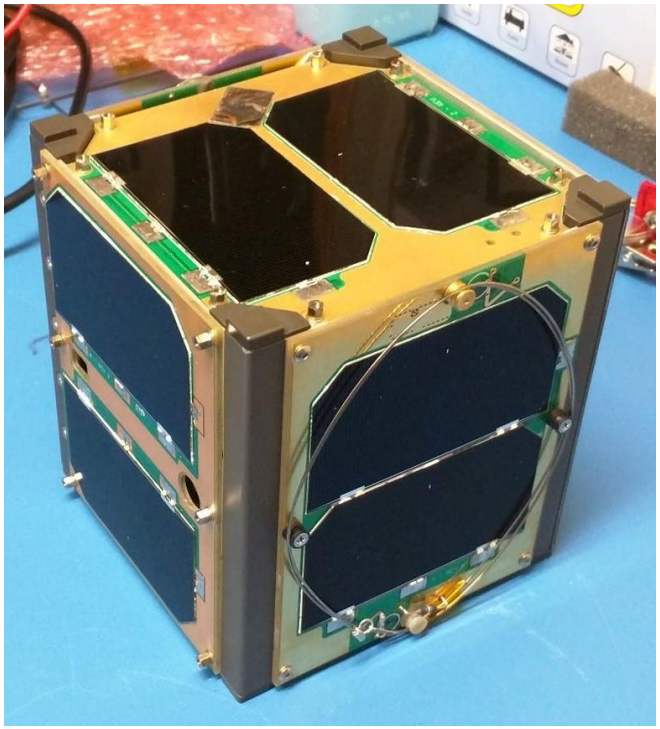
Duke City Hamfest, August 11, 2017

Who is Abigail Bass?

- **KG5QDE**

- First Licensed in 2016 as Technician
- Earned General in June 2017
  - Valley High School Summer School
  - Dual Credit Class with APS and CNM
    - 3 Weeks
    - 5 Days per Week
    - 10 Hours / Day
    - 40% Theory, 60% Hands-On
    - Supported by HDARC & Industry Mentors
  - Field Day 2017 (A High Point)
  - STEM Super Computing Club
  - JROTC

CubeSAT: NM-RADSAT-1



- **3-Year project**
  - Year 1 – Proof of Concept
  - Year 2 – Prototype
  - Year 3 – Production
  - Then …… Launch & Operation

- **Working with AMSAT**
  - Joe Spier, K6WAO
    AMSAT NA Exec VP
    Former Asc Director for Education
  - AMSAT came to class and spent 2 days talking about CubeSATs and value of education

- **Working With Industry Mentors & Instructors**
  - Chuck Newman, Alma Ripley, Connor Neal
  - Bill Ripley (KY5Q), Brame Tech / Alligator Designs
  - Bodgan Pathak, Richard Valdez (Sandia Labs)
  - HDARC (Guyline Pollack, Larry Elkin, Jerry Aceto, Ed Poccia)
  - Sandy McIntosh (SpaceX), Brian Neal (APS, APD)

NM-RADSAT-1 Proof of Concept

- **Proof of Concept (PoC) Hardware**
  - Similar **Function** as the real CubeSAT Hardware
    - To Learn What Works and What Doesn't
  - Build PoC, and then Fly on High Altitude Balloon Missions

- **Communications**
  - Voice Repeater
    - Primary: Mode UV (UHF In / VHF Out)
    - Secondary: Mode VU (VHF In / UHF Out)

- **Photographic Imagery**
  - Daylight Video Camera (432 MHz ATV)
  - Daylight Still Camera

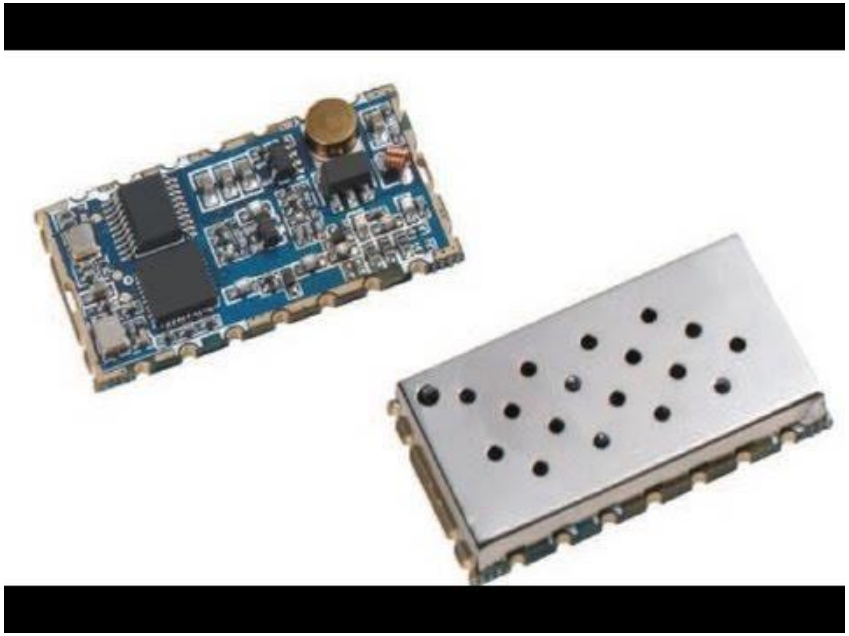
- **Telemetry & Control**
  - Touchtone on UHF (70 cm)
  - APRS Data With GPS Position, Component Temperatures, Orientation (Pitch, Roll, Yaw)
  - AMSAT Fox Series **DUV (Data Under Voice)**

PoC Cross-Band Repeater

- **Selectable Mode UV / Mode VU**
  - Touchtone
- **We Selected Dorji RF Modules for Proof of Concept**
  - Like a Baofeng Chinese Radio in Tiny Package
  - Module #1: VHF TX/RX
  - Module #2: UHF TX/RX
- **We Selected NHRC-u Repeater Controller**
  - CW ID
  - Touch Tone or Serial Control from system computer
  - Hang Timer and Timeout Timer
  - COR or CTCSS
- **Basic Repeater First, Add AMSAT DUV Telemetry Second**

Dorji TX/RX Modules

- **Programmable Transceiver**
  - VHF or UHF Module
  - 1 Watt Output (Adjustable)
  - High Sensitivity (-122 dBm)
  - Postage Stamp Sized
  - Highly Integrated
  - Requires MicroController



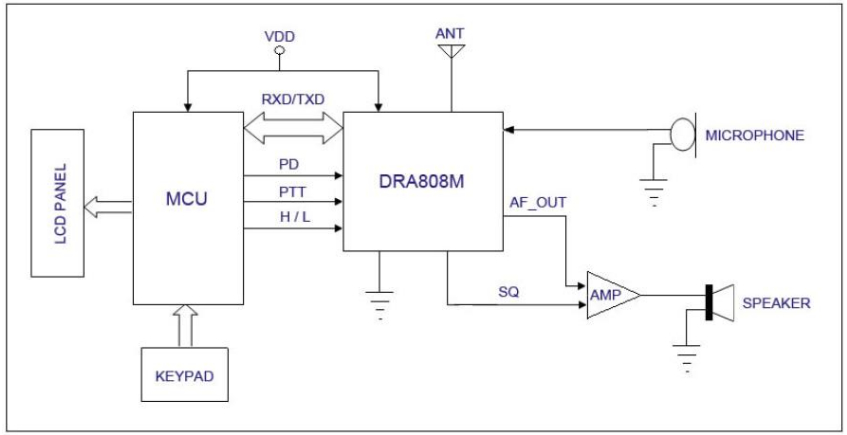


Figure 3: DRA818U Application Circuit

Experience With Dorji TX/RX Modules

- **First Prototype – Crashed & Burned**
  - Breadboard design with no PCB had problems with noise and intermittent operation.
  - Unit could not remember settings from one power cycle to another

- **Back to the Drawing Board**
  - Found a project from a ham in Europe who had built a PCB with Dorji module, microcontroller and basic firmware
  - Used PCBs from **Weekend Radio Project** which uses the DRA818U and DRA818V
  - Will start with his microcontroller firmware and customize it for our use
    - The microcontroller is an Atmel AVR with BASCOM AVR Software Tools
  - We are 95% complete building the PCBs.
    - Will finish hardware & firmware by Sept 1

NHRC-u Repeater Controller

- **Repeater Controller comes assembled from NHRC**
  - We did custom set-up for this application.
  - Will interface with separate home-made board to change control signals and audio to switch between Mode UV and Mode VU
  - Programmed very easily and quickly

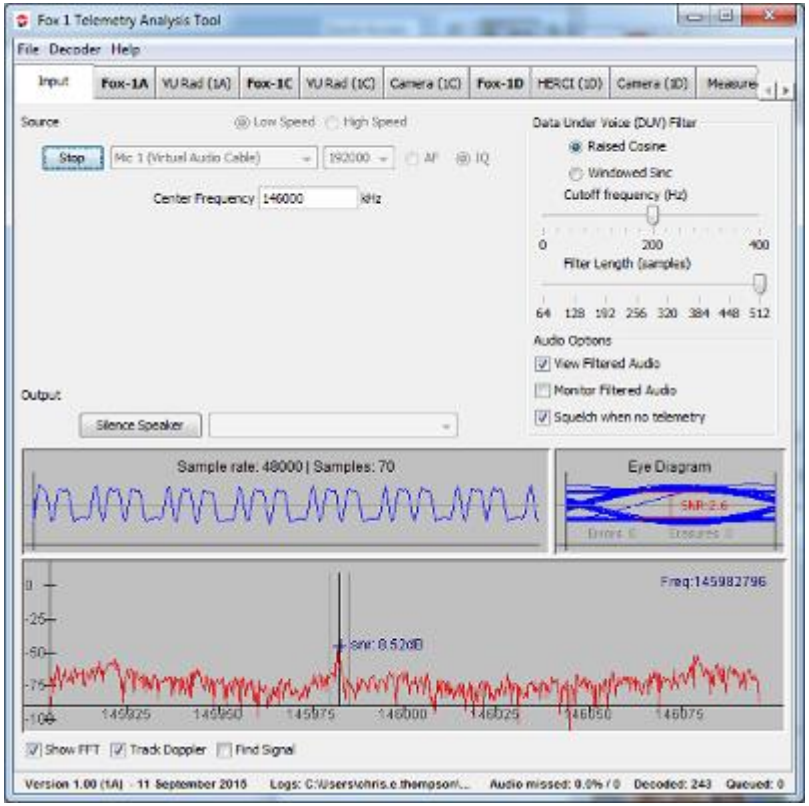
Integrated PoC Cross Band Repeater

- **Test first in the lab**
  - Receiver Sensitivity
  - Selectivity
  - Spectral Purity
- **Fly on High Altitude Balloon**
  - Flight to 100,000 to 125,000 Feet
  - -50C Ambient Temperature
  - Should allow communications for hundreds of miles
  - Pretty good test under rugged conditions
- **Dorji Modules are not suitable for Space Use because they don’t have Temp Compensated Crystal Oscillator (TCXO)**
  - Future versions might have TCXO Input
  - AMSAT is looking for a good highly integrated TX/RX Module

AMSAT Telemetry - Data Under Voice (Goal)

- **FoxTelem Software Telemetry Decoder**
  - Available through AMSAT
  - Used for AMSAT's "Fox" Series of CubeSATs
  - By using this format, stations around the world will be able to monitor, download and utilize data from our CubeSAT.
  - Available for Windows, Linux, MacOS

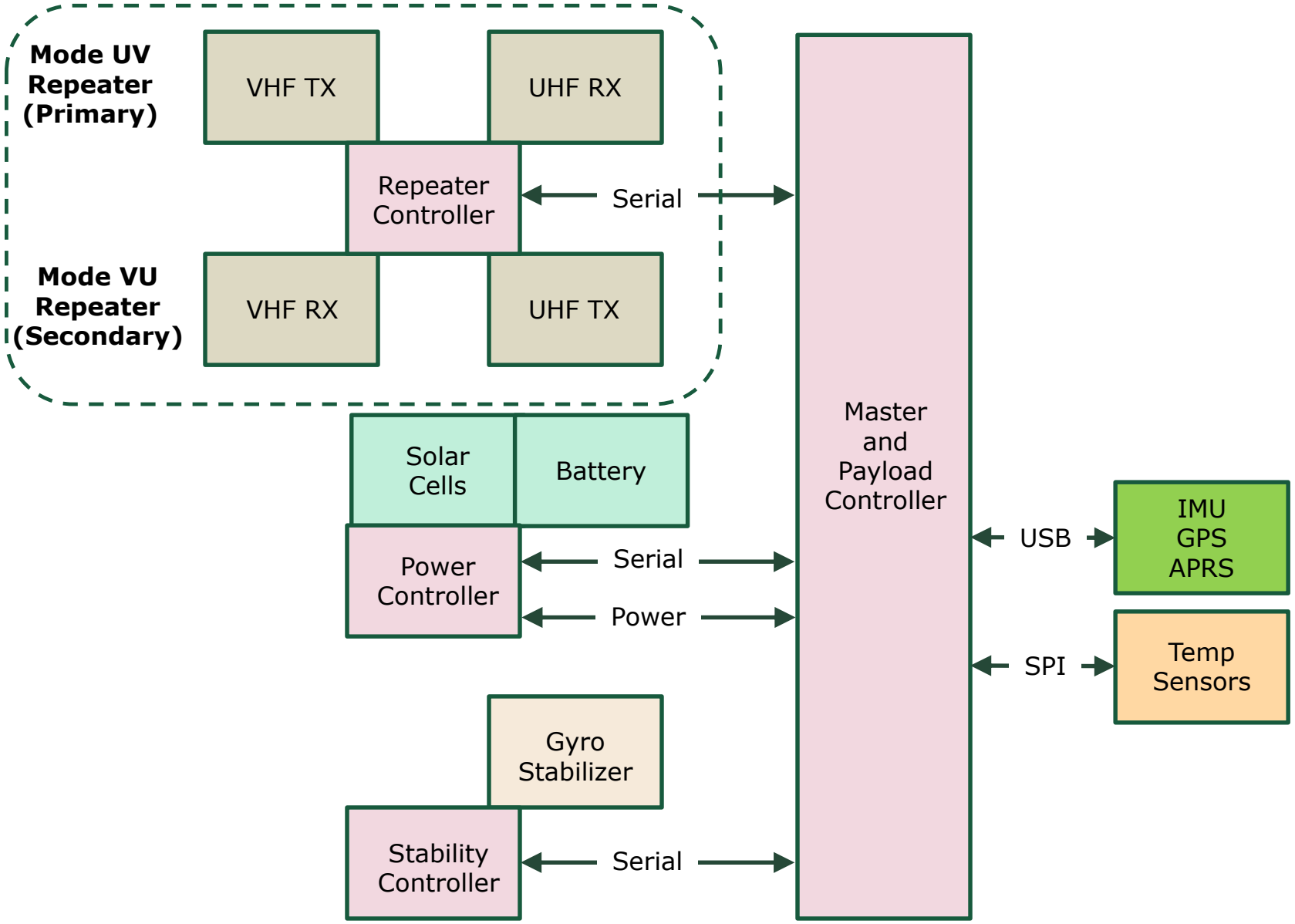
- **How Does it Work ???????**
  - Everything **over** 300 Hz on Audio Channel is "Voice"
  - Everything **under** 300 Hz on Audio Channel is DUV, i.e. "Data"



Download FoxTelem User Manual

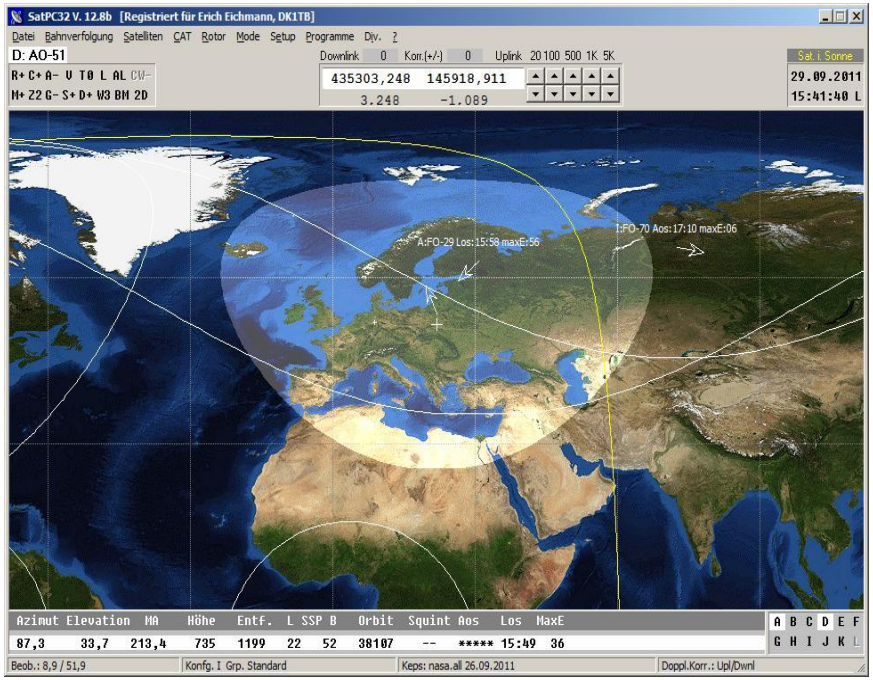
http://www.amsat.org/wordpress/wp-content/uploads/2015/09/foxtelem_manual_100a.pdf

Proof of Concept CubeSAT Block Diagram



Ground Station

- **AZ-EL Rotor**
  - Homebrew WRAPS Rotor as shown in QST
    - Portable and relatively inexpensive system to track satellites and balloons
- **VHF and UHF Antennas**
  - Homebrew Yagi antennas
  - Kent Britain design from QST
  - 8 Element on UHF
  - 4 Element on VHF
- **AMSAT Software**
  - SATPC32



Thank You

Questions? Please contact

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