Advanced Communications Package

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ACP Vision

- Create a payload ***<u>and matching ground segment</u>*** for Eagle which will:
  - enable new ham radio applications and activities
  - be accessible to hams not already on satellites
    - Low cost
    - Small, simple, CC&R-friendly antennas
    - Interesting uses and applications
  - Provide emergency communications capabilities superior to what the pros have

Vision, cont'd

- Investigate technologies for future missions
  - Continuously available worldwide constellation
- Create flexible systems usable terrestrially
- Complete ground stations available ***before*** launch
  - one stop shopping
- Flexibility
- Have fun

Not Part of Vision

- Allow users to reuse AO40 (or other) equipment
- Analog Modes
- Transponder
- Yet another “big-guns only” system
- Internet replacement
- Build your own ground station
- Any particular band or technology

Proposed Capabilities

- Send bits up and down
- System shouldn't care what they represent (Audio, Video, Photos, Data, etc.)
- Asymmetric up/down links
- Scalable data rates to enable different classes of users stations

Digital Comms Payload

- S2-Band (3.4 GHz) Down, 10 MHz wide
- C-Band (5.6 Ghz) Up, 20 MHz wide
- ~43 Patch antennas for each band
  - Phased Array, amplifier per antenna
  - Steer Digitally (if we really need to...)
- Software Radio Digital Comms Hub
  - Digital Voice (4.8kpbs), up to 500 channels!
  - Digital Data (2.5Mbps peak)
  - Only multiplexing and maybe QoS
    - state, intelligence, apps in ground stations

Class 1 - Handheld

- Useful for
  - emergency comms, demos for schools,
  - autonomous data collection
  - weather, terrestrial telemetry
  - HT-like apps
- 1W TX power
- Small antennas, hand-pointed
  - no more than 8-10 dB gain
  - Patch? helix?

Class 2 – Small Fixed

- Useful for
  - Emergency command stations
  - Video
  - High quality digital voice
  - General bulk data transmission
- 5 Watts TX power
- Small, inconspicuous antenna
  - 2 Foot dish
  - Easy to aim, wide beamwidth

Class 3 – Big Gun

- Not needed.
  - Save your money.
    - Buy your spouse something nice.
      - From somewhere other than a hamfest....

Data Rates

- Class 1
  - ~500 bps up
    - 1.2 kbps digital voice in bursts, a la Nextel
    - Data, telemetry, APRS, paging, etc.
  - 50 kbps down to mobile stations
    - Full digital voice, data, telemetry, etc.
- Class 2
  - 100 kbps up, 2.5 Mbps down to small fixed stations
    - High quality digital voice, data, digital video, etc.
- Satellite apportions downlink capacity dynamically
  - Class 1 and Class 2 can talk to each other

Note...

- All data rates are based on the following
  - Geosync orbit
  - 200W Satellite TX Power
  - 5dB Eb/N0
  - KA9Q's path loss spreadsheet
  - Lots of back of the envelope calculations, approximations, guesses, etc.
    - Many system parameters still unknown

Uplink Multiple Access Choices

- FDMA
  - Low peak power (can TX continuously)
  - More complex receiver
  - Tougher to QRM
  - Coordination may still be necessary
- TDMA
  - High peak power, Difficult to coordinate
  - Inefficient with high latency paths
- CDMA
  - Mutual Interference
  - Low peak power

Uplink Modulation Choices

- Similar constraints to downlink (power is expensive, bandwidth is cheap)
- Additional constraint of complexity of demodulation for the satellite (must demod many channels simultaneously)
- Unfiltered BPSK or MFSK
  - Don't necessarily need to choose ahead of time

Chosen Uplink System

- Unfiltered BPSK, possibly with residual carrier
- FDMA
  - Many (hundreds) of uplinks demodulated in parallel
  - Enough uplink bandwidth for everyone to get their own frequency
    - Uplink frequency assignment a combination of random and Least-Recently Used (LRU)
    - All users uplink at whatever rate they need and for which they have the power and gain (no class 1 or 2 distinctions)
- Conventional convolutional code + Reed-Solomon
  - Could use turbo code, but demod is expensive

In-Satellite Processing

- Demodulate, decode
- Minimal state, packet interpretation, or policy
- Basic packet prioritizing, QoS
- Most policy stuff handled in ground stations
  - Satellite doesn't care who is talking to whom
  - Just reflect bits
- Encode, Modulate

Downlink Multiplexing Choices

- Separate signals to separate users
  - Simpler receiver
  - Multi-carrier PA necessary
  - Harder to scale, coordinate
- One signal with multiplexed data
  - Single carrier
  - Can still proportion power and coding differently
    - Give signals going to small users more time (power)
    - Prioritize traffic
  - Simple TX amps and modulators
  - Users can receive multiple streams easier

Downlink Modulation Choices

- ~~We have more bandwidth than we can use~~
  - ~~Narrowest band under consideration is 10 MHz~~
  - ~~We should use as much bandwidth as we like~~
- We are power limited
  - Peak transmit power limited by devices
  - Total consumed power limited by ~~solar array~~ hosts
- We should use a modulation system with a constant envelope to enable the most efficient use of our energy
  - Can use a Class-C or Class-E amp

Downlink Modulation Choices, II

- Unfiltered BPSK
  - Constant envelope, Power efficient
  - Easy to demod, Coherent reception
  - Used by GPS satellites
  - If main signal is weak, no need to worry about sidelobes
    - Not so weak anymore...?
- MFSK
  - Constant envelope
  - Power efficient for relatively large M (>=16)
  - Easy to demod

Downlink Specifics

- 5 Megasymbols per second unfiltered BPSK
  - Results in sidelobes outside satellite band...
- Turbo Coding (or turbo + RS)
  - Code Blocks of 1800 bits
  - Multiple voice (or other low rate) streams combined into single blocks
    - Lower latency – don't have to wait for a full block
    - Pad with telemetry, or repeats of data
- Code blocks preceded by one of two sync codes
    - “This is a new block” OR
    - “This is a repeat of last block”

Downlink, cont'd

- Class 2 users
  - Rate ½ code (3600 symbols/block)
  - Blocks intended for Class 2 users sent once
  - Max capacity ~2.5 Mbps (5Msps / 2)
- Class 1 users
  - Rate 1/6 code (3 blocks of 3600 symbols)
  - Blocks intended for Class 1 repeated ~16 times
  - Max capacity ~50kbps (5Msps / 6 / 16)
  - Class 1 user can have an ~18dB worse antenna
    - Power gain of ~17dB (48x) vs. Class 1
    - Coding gain of ~1.2dB vs. Class 1 (rate 1/6 vs 1/3)

Ground Station Projects

- S2/C dual-band antennas
  - Feed and small dish combo (class 2)
  - small antenna for class 1 systems
    - Quad helix? Patch? Other?
- 5 GHz nonlinear PA + upconverter
  - Class 2 -- ~5W
  - Class 1 -- 250mW
- 3.4 GHz LNA + downconverter

Satellite Projects

- Phased Array
  - Modeling
  - Element design (probably patches)
  - Phasing system
- C-Band LNA and mixer
  - Must be very low power, ~43 instances
- S2-Band PA and mixer
  - Highly efficient, ~43 copies
  - ½ to 5 Watts apiece, depending on power budget
    - TBD...

For more info, To participate

- amsat.org
  - EaglePedia (Wiki)
- Email
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