The AMSAT-Intelsat Project and the Advanced Communications Package

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Intelsat Opportunity

- Ride on another satellite to GEO
- 2 Major payloads, SDX and ACP
- Pros
  - Always visible, no rotators
  - 3-Axis stabilization, lots of power
  - Don't need to worry about anything but the payloads
- Cons
  - Not cheap
    - Will need to find outside funding sources
  - Have to work closely with an outside organization
    - NDAs, MOUs, etc.
  - Europe / Asia not served well

SDX

- Software Defined Transponder
- 100-200kHz wide passband
- Similar architecture to SDR-1000
- Advanced software algorithms
  - Power leveling – no more alligator problems
  - Low power paging services, digital demods
  - Lots of flexibility
- Very high efficiency transmitter
  - Class E + Drain Modulation (EER) + DSP
- Combined V/U/L/S, 2 input bands, 2 output

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

Capabilities

- Send bits up and down
  - System doesn't care what they represent (Audio, Video, Photos, Data, etc.)
- Asymmetric up/down links
- Scalable data rates to enable different classes of users stations
- S2-Band (3.4 GHz) Down, 10 MHz wide
- C-Band (5.6 Ghz) Up, 20 MHz wide
- Software Radio Digital Comms Hub
  - Digital Voice (4.8kpbs), hundreds of channels
  - Digital Data (2.5Mbps peak)
  - Multiplexing and QoS

In-Satellite Processing

- Receive, Demodulate, Decode
- Minimal state, packet interpretation, or policy
  - state, intelligence, apps in ground stations
- Basic packet prioritizing, QoS
  - Multiple Queues for different traffic classes
- Most policy stuff handled in ground stations
  - Satellite doesn't care who is talking to whom
  - Just reflect bits
- Encode, Modulate, Transmit

Class 1 - Handheld

- Useful for
  - emergency comms, demos for schools,
  - autonomous data collection
  - weather, terrestrial telemetry
  - HT-like apps
  - Optional USB Connection to a PC
- 1-5W 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
- USB or Ethernet connection to a PC
- 5-10 Watts TX power
- Small, inconspicuous antenna
  - 2 Foot dish
    - So it looks like a DSS system...
  - Easy to aim, wide beamwidth

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
  - 50 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 - FDMA

- Pros
  - Simple TX
  - Low peak power (TX continuously, unlike TDMA)
  - No multiple-access interference (unlike CDMA)
  - Enough uplink bandwidth that every user can basically have their own channel
  - Tougher to QRM
- Cons
  - Frequency coordination may still be necessary
  - Complex (massively parallel) receiver in the satellite
  - Requires decent linearity in receiver
  - Narrow bandwidth channels make frequency accuracy and phase noise requirements tougher

Uplink Modulation

- BPSK
  - Power is expensive, bandwidth is cheap
  - Easy to mod and demod
  - Unfiltered or RRC filtered
    - Use unfiltered for best power efficiency
    - Use filtered when band is crowded for best bandwidth efficiency
    - Don't necessarily need to choose ahead of time
- Convolutional Coding concatenated with Reed-Solomon
  - Well proven, simple for satellite to demod
  - Could use turbo codes, but would make the satellite's job harder (remember the satellite neeeds to do 3000+ in parallel!)

Downlink Multiplexing

- Rather than separate signals to separate users, send just one signal with multiplexed data
  - Single carrier, efficient amps
  - Can proportion power and coding dynamically
    - Give signals going to small users more time (power)
    - Prioritize traffic
  - Simple TX amps and modulators
  - Users can receive multiple streams easier
- Con
  - Receiver must receive and decode the fast stream (possibly as fast as 2.5 Mbps)

Downlink Modulation

- Again, bandwidth is cheap, power is expensive
  - We have more bandwidth than we can really use, given our power limitations
  - We should use as much bandwidth as we find useful
- We are power limited
  - Peak transmit power limited by devices
  - Total consumed power limited by host bird and dissipation limits
- Use unfiltered PSK
  - Could be BPSK, QPSK, OQPSK, or Pi/2-BPSK
  - If main signal is weak, no need to worry about sidelobes
    - Not so weak anymore...?

Downlink Modulation, II

- Pi/2-BPSK
  - Just like BPSK, except +/- 90 degree transitions instead of 0/180 so envelope doesn't go to zero
  - Constant envelope, Power efficient
  - Easy to demod, Coherent reception
- OQPSK
  - Just like QPSK, but phase changes are offset/staggered
  - Envelope never goes to 0
  - Easy to demod, Coherent reception
- QPSK/OQPSK take up half the bandwidth of BPSK or Pi/2-BPSK
- QPSK/OQPSK carrier tracking somewhat harder

Downlink Specifics

- 5 Megasymbols per second
- 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)

How to get involved

- We need many people with many different skills
  - Space-qualified hardware design
    - Especially FPGAs
  - RF Design
  - Antenna Design
  - Digital design
  - Communication systems
  - Compliance, EMI, EMC, testing
  - Networking
  - Software, firmware
  - Web design and administration
  - Publicity
  - Marketing
  - Emergency Communications

For more info, To participate

- amsat.org
  - EaglePedia (Wiki)
- Email
  - matt@ettus.com