Northern SPIRIT Mission Objectives and Implementation

May 05, 2021
AlbertaSat GAM

Meeting the Northern SPIRIT Mission Objectives

Using Software-Defined Radio (SDR) to games, voice, and images

Presentation Outline

A. Northern SPIRIT Mission Objectives
B. Considerations specific to Northern SPIRIT
C. UHF radio capabilities
D. Proposed solution
E. Challenges

Northern SPIRIT Mission Objectives:

- Earliest references in Canadian CubeSat Project Proposal; Aurora Research Institute of Aurora College, Dec 14, 2017, Section 4.1.x; implementation details not specified

4.1.1 The goal of the Northern Images mission is to display northern art in a way that is new and unique.

4.1.2 The goal of the Northern Voices mission is to respond to amateur radio operators all over the world with stories and phrases in a collection of Indigenous languages. [...] The payload team will collaborate with AlbertaSat and AMSat to ensure that the UHF/VHF transceivers on board are capable of transmitting voice data stored on the payload device itself.

4.1.3 The Northern Games mission will create a globally interactive game for amateur radio operators to participate in. Special recordings played only in certain geographic zones… The payload development for this mission will mirror closely the development of the Northern Voices mission. The primary difference on this mission will be the requirement for the payload team to integrate GPS data into the voice data transmission algorithm...

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Northern SPIRIT Mission Considerations:

- Maximum transmit/receive time is ~10 minutes
- Start of down transmission is arbitrary wrt ground location
  - Therefore, max story length of ~5 minutes at most
- Upload must be digital, which is actually good
  - Story data can be compressed
  - Can be uploaded multiple times in 10 minute window to increase chance of success
- Images are digital, VGA or QVGA
  - VGA (640x480) 50% 40-70 kB
  - No FEC; req ~1870 bps user, ~1900 bps with overheads
  - With FEC; req ~3740 bps user encoded, ~3800 bps with overheads
  - QVGA (320x240) 50% 20-40 kB
  - No FEC; req ~1070 bps user, ~1200 bps with overheads
  - With FEC; req ~2140 bps user encoded, ~2300 bps with overheads

Does the proposed solution meet the objectives?

Hinges on the following

- What capability do amateur FM transceivers possess?
- What will an amateur/enthusiast need to do to receive digital voice & images?
- What extra costs need to be incurred?
  - For licensed amateurs
  - For general interested public (enthusiasts)
- What impact is there to the program schedule?
- What advantage is there to digital?
- What precedents?

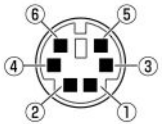
Amateur Radio capabilities

- All analogue FM radios are capable of 1200 bps reception
    - ARRL “Choosing a HAM Radio”, ttps://www.arrl.org/files/file/On%20the%20Air/Choosing.pdf
- Needed digital radio for beacons (AX.25 packet), can be done in 1200 bps
- Around *1988* K9NG and G3RUH determined that FM transceiver can support 9600 bps reception
    - 8 kHz BW direct from FM discriminator https://www.amsat.org/amsat/articles/g3ruh/109.html
- The big 3 ham radio manufacturers (Kenwood, Icom, Yaesu) standardized on the same 6 pin mini DIN connector. Alinco has the same functionality but a different connector.
- The 9600 pin comes right from the discriminator without de-emphasis. This has enough bandwidth for 9600 baud data.
- Lot of support for this approach; https://github.com/wb2osz/direwolf-presentation

Kenwood TM-D710GA

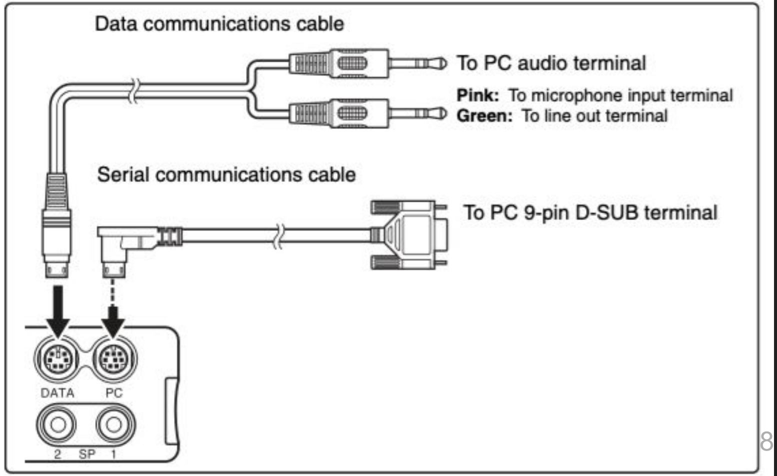
- Computer’s sound card is input
- GNU Radio “Audio Sink” block receives 1200 bps or 9600 bps data
- Known as the “9600 port” [1]
  - This 9600 port is used to communicate with some amateur radio satellites using the packet radio

DATA terminal pins



- When using the built-in TNC, the DATA terminal is not used.

No.	Name	I/O	Function
①	PKD	I	Audio signal for packet transmission
②	DE	—	PKD terminal ground
③	PKS	I	‘L’ is transmitted and the microphone is muted
④	PR9	O	Detected 9600 (bps) data
⑤	PR1	O	Detected 1200 (bps) data
⑥	SQC	O	Squelch control signal; Closed: ‘L’, Open: ‘H’ (The default settings can be changed in Menu 921)



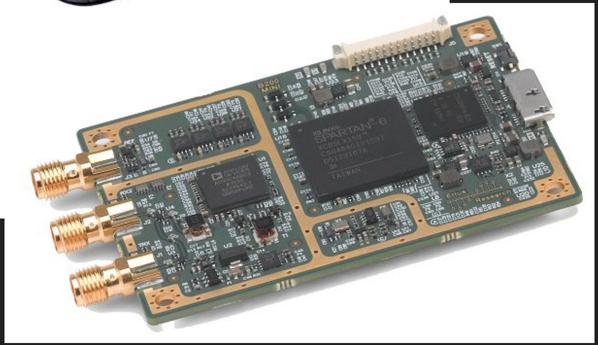
[1] https://en.wikipedia.org/wiki/9600_port

What does an amateur require to receive?

- Reasonably recent FM Transceiver (VHF/UHF)
- Laptop or PC
    - Could be Raspberry Pi with audio card
- DIN 6 data cable
    - ~ $CA 20 - 60 (DIY to Kenwood)
- GNU Radio; open source, free, well-supported
    - Laptop or PC, or
    - Raspberry PI + card < $CA100

What does an enthusiast require to receive?

- Laptop or PC
  - Could be Raspberry Pi ~ $CA80
- Three levels of SDR
  - RTL-SDR ~ $CA20 to $CA40
  - Pluto SDR ~ $CA220
  - USRP ~ $CA1100 to $CA1600
- Antenna ~ $CA50
- Cables ~ $CA50



Differences have to do with receive sensitivity.

All will work

Development Impact

- Have always required digital modulation for image transmission; no impact
- Needed COTS radio firmware modification to support FEC
  - Manufacturer has made the change; no impact
- Need to develop FEC and digital transmission of voice and images
  - FEC; use existing proven capabilities; ~ 2 months work
  - Custom packets; ~ 1 month work
  - Integration and test; ~ 2 months work
  - Independent of other work, so can be in parallel
  - Impact minimal for time, require extra resources (people)
- Development based on tried and proven software
  - LiquidSDR + custom C code for transmitter side
  - GNU Radio + custom C/C++ code for receiver side
  - All can be open source, with detailed instructions for interested parties

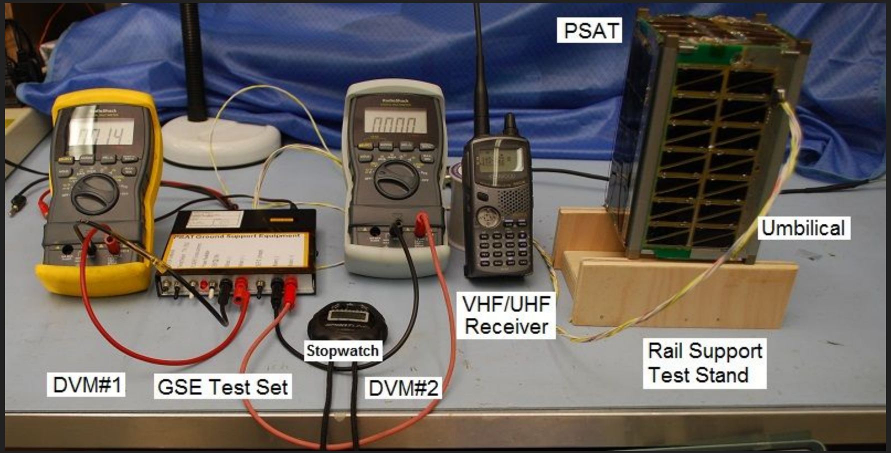
Precedents : LilacSAT-1, LilacSAT-2

- Harbin Institute of Technology student built
- Deployed from ISS May 25, 2017
- Analogue FM uplink, Codec2 1300 bps digital voice downlink
    - FM Uplink 145.985 MHz with 67 Hz CTCSS (PL Tone)
    - Codec2 9600 bps BPSK Downlink 436.510 MHz
- Could have used Codec2 2400 or 3200 for even better sound quality
- Local users able to transmit their own voice up and have it sent back down in digital format
- E.g., FUNcube dongle used to receive data

https://destevez.net/2016/10/lilacsat-1-codec-2-downlink/
http://lilacsat.hit.edu.cn/wp/

Other Satellites using 9600 bps

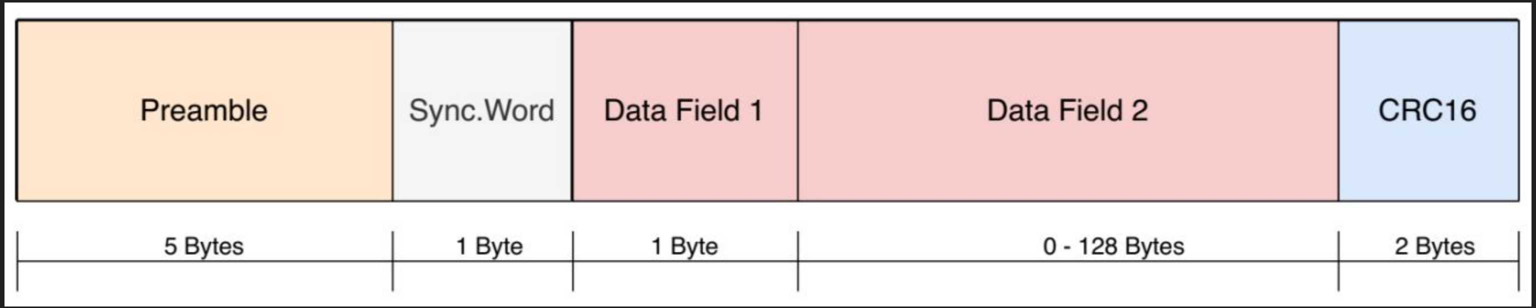
- http://aprs.org/bricsat2.html (2019)
- http://aprs.org/psat2.html (2014)
- https://www.amsat.org/falconsat-3/ (2007)
- https://www.amsat.org/two-way-satellites/no-44-pcsat/ (2001)
- http://aprs.org/psat.html (2015)

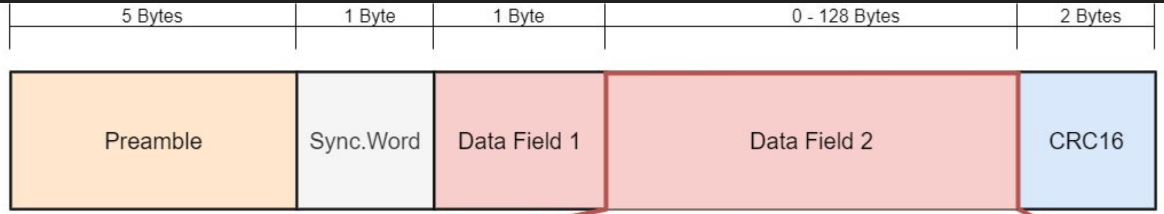


Proposed Solution Conclusions

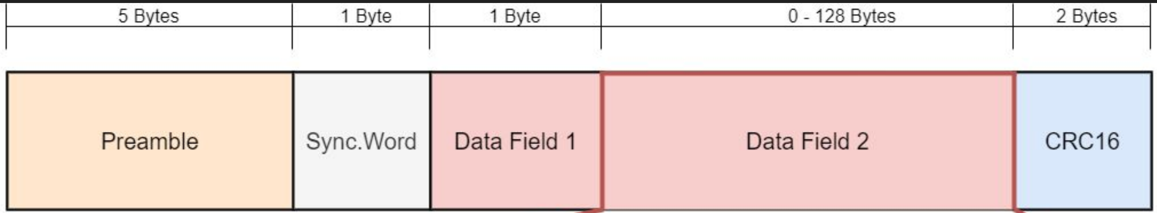
- Common amateur equipment and inexpensive SDRs can receive
    - Beacons at 1200 bps or 9600 bps
    - Voice and images at 9600 bps
- Cost range for amateurs is $CA 0 to 60
- Cost range for enthusiasts is $CA 120 to 1700
- 9600 bps downlink can support separate voice and image data, or mix
    - 40-80 kB image, Codec2 3200 bps voice
    - Optimum mix is TBD
- Codec2 voice quality is very good; speaker easily recognized
    - Pre-recorded transmissions can be verified for quality on the ground
- Digital more likely to be received than equivalent analogue approach
- Many amateurs replacing analogue with SDR

UHF Radio Packets





	AX.25 Frame											
		AX.25 Frame Header										
Preamble	Flag	Dest. Addr.	SSID	Src. Addr.	SSID	Control	PID	Information Field	FCS	Flag	Postamble	Field Description
64	8	56	8	56	8	8	8	1024	16	8	24	Bits
8 * 0x7E	0x7E	ASCII	0xE0	ASCII	0xE1	0x03	0xF0	Hex		0x7E	3 * 0x7E	Contents
		Dest. Callsign		Source Callsign				32 - 776 bits/data	CRC16-CCIT			Comments
		Bit stuffed ('0' added after 5th '1', removed on the other end)										Bit stuffing
Scrambling per G3RUH/K9NG, and UoSAT-14/22/23 *												Scrambling
NRZI encoding												Encoding for transmission



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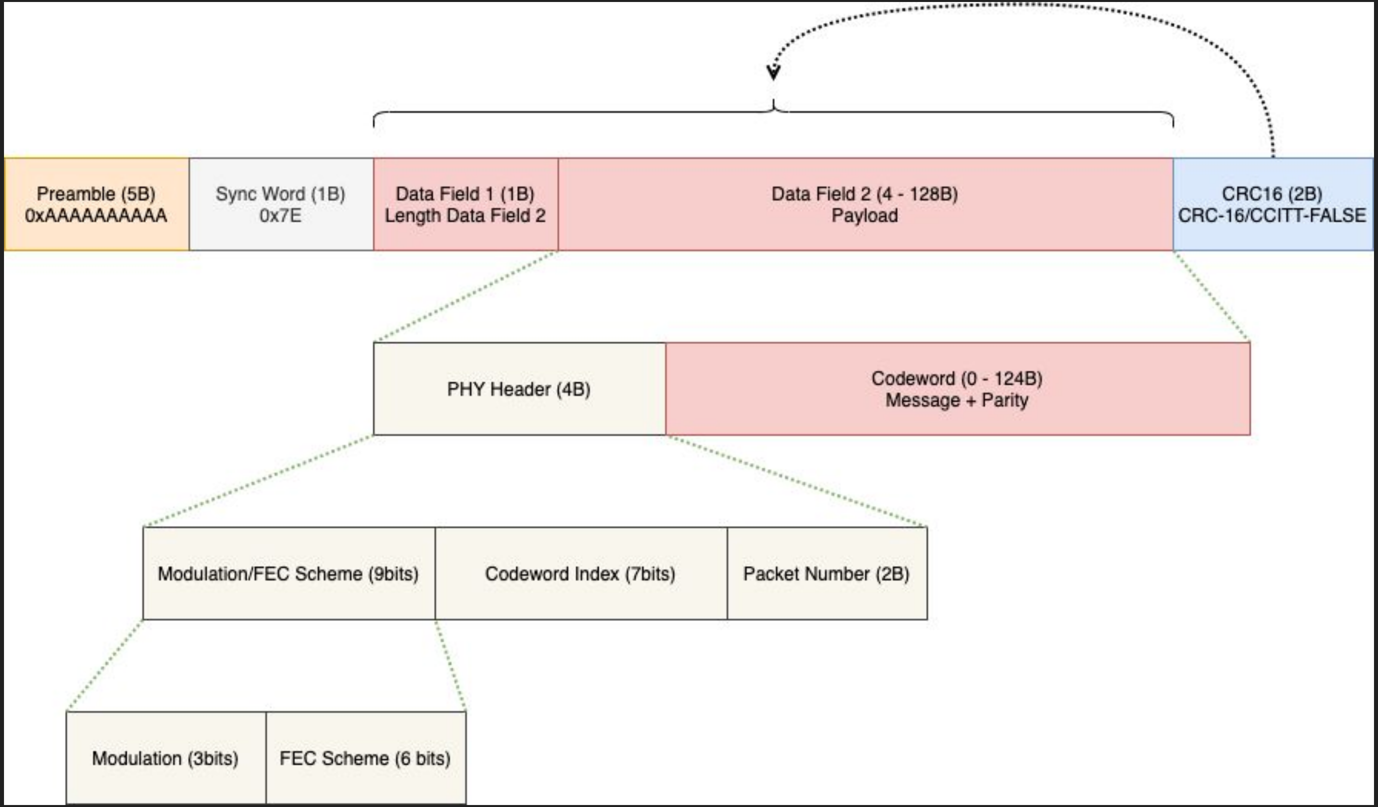
760 bits
95 bytes

Transparent Mode (PIPE) packet



See transparent packet format doc for definition of PHY header and modulation+FEC schemes enums.

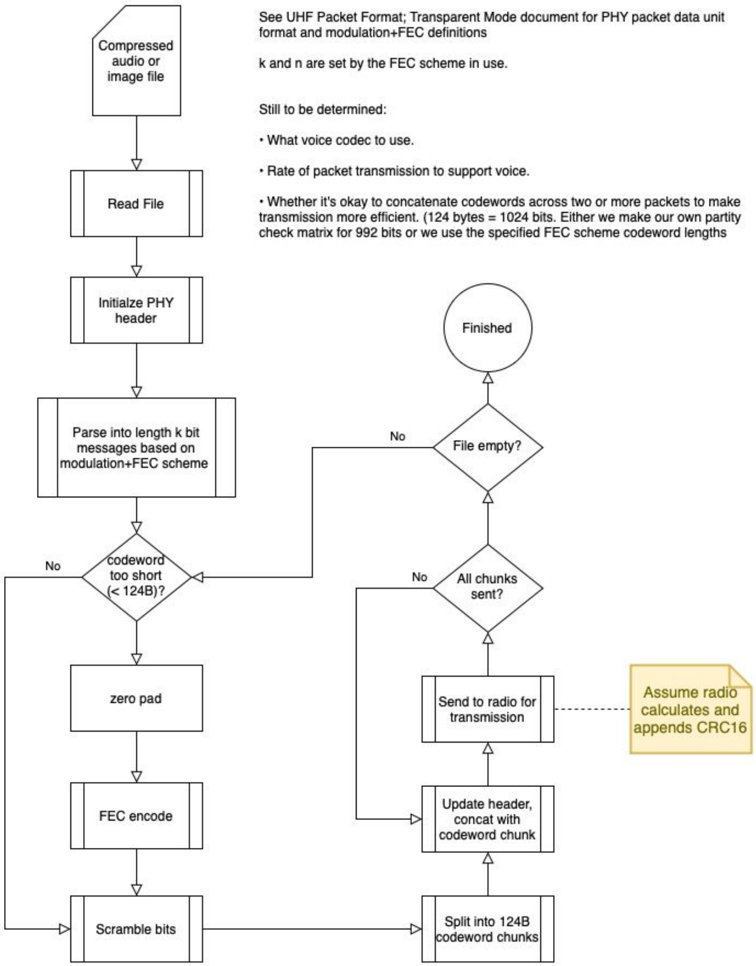
A message is k bits, a codeword is n bits > k

See UHF Packet Format; Transparent Mode document for PHY packet data unit format and modulation+FEC definitions

k and n are set by the FEC scheme in use.

Still to be determined:

- What voice codec to use.
- Rate of packet transmission to support voice.
- Whether it's okay to concatenate codewords across two or more packets to make transmission more efficient. (124 bytes = 1024 bits. Either we make our own partity check matrix for 992 bits or we use the specified FEC scheme codeword lengths



Challenges

- Do we need CRC16 on PHY Header
  - Trade-off for reliability vs user bandwidth
- Support for Eigen3 — sparse matrix math
- How many different FEC schemes to implement and test
    - Want at least 2 at ≥ 3 rates each
    - Trade-off between performance and computational complexity
      - Impacts satellite and ground station choices
- Time and effort risk
    - OBC implementation is highest priority

What’s Next

Later in summer another presentation on ground station work

Questions?