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The Netherlands, 26th November 2010

RAX Telemetry
Decoding Effectiveness Experiment

Radio Aurora Explorer (RAX)

The objective of the RAX mission is to understand the microphysics that lead to the formation of magnetic field-aligned plasma irregularities (FAI), an anomaly known to disrupt communications with orbiting spacecraft.

Objective of the Experiment

Objective:

“Analyze the effectiveness of a Radio Amateur Satellite Station to serve as a Ground Station (GS) for RAX”

Method:

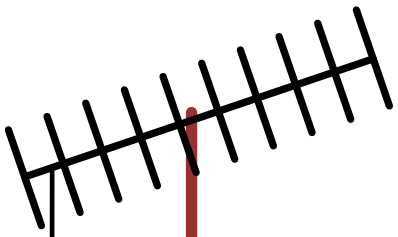
During 24 hours the GS monitors independent and fully automated (computer controlled) the RAX downlink.

RAX sends each 20 seconds a data packet.

Based on the amount of successfully decoded telemetry packets an indication for the **“RAX decoding effectiveness”** can be derived.

Ground Station Architecture

PA3GUO Satellite Ground Station



437 MHz

Rotor

Pre-amp

Rotor Controller

Receiver

9k6 GMSK

TNC

RS232

PC

Rotor Control

Ham Radio Deluxe

RAX GS Client

Satellite Tracking

Doppler Control

Data Processing

University Michigan

internet

Ground Station Equipment

Hardware

Antenna	12 elements, vertical polarization
Pre-amp	SSB Electronics SP-7000
Rotor	Kenpro KR-500 + KR-400
Receiver	Kenwood TS-2000X
TNC	AEA PK-96

Software

Doppler Control	Ham Radio Deluxe
Rotor Control	PA3GUO
Data Analysis	MSI RAX GS Client

Ground Station Components

Antenna:
12 elements directional yagi (PE1ITR)
Vertical polarization
Satellite tracking in steps of <5 degrees (azimuth & elevation)
UHF (437MHz) SSB Electronics pre-amp used for improved SNR

Receiver:
Kenwood TS-2000x, multi-mode transceiver
Frequency control (Doppler compensation) via HamRadioDeluxe
PK96 TNC to decode the 9600 GMSK downlink of RAX

Software:
Alogger to initialize the TNC into KISS mode & 9600 baud
RAX GS Client to decode and store & forward the telemetry

24 hour window: Nov 25 2010

Passes:
RAX passes a GS each day multiple times.

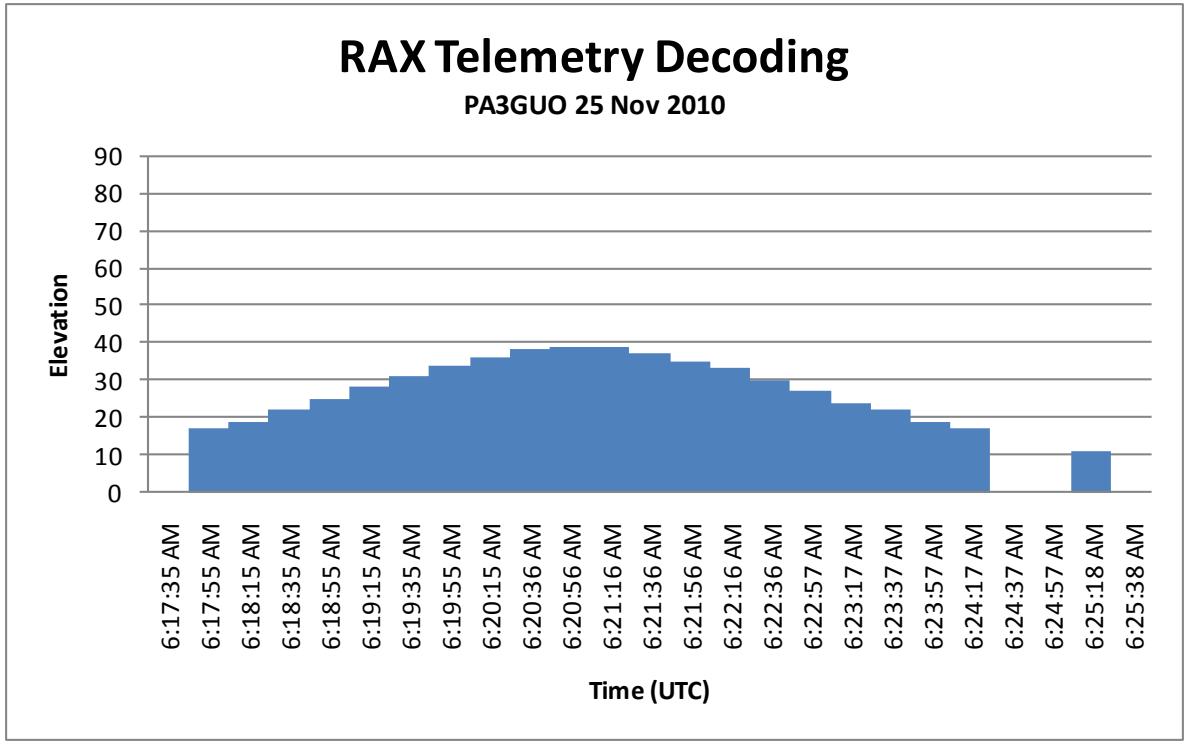
Some passes have a high maximum elevation during which many packets are decoded due to the good S/N ratio.

Low elevation passes (<20 degrees) typically result in fewer data.

Nov 25 – Nov 26 had these 5 passes:

06:20utc	40° elevation
08:00utc	11° elevation
13:05utc	28° elevation
14:45utc	52° elevation
05:05utc	68° elevation

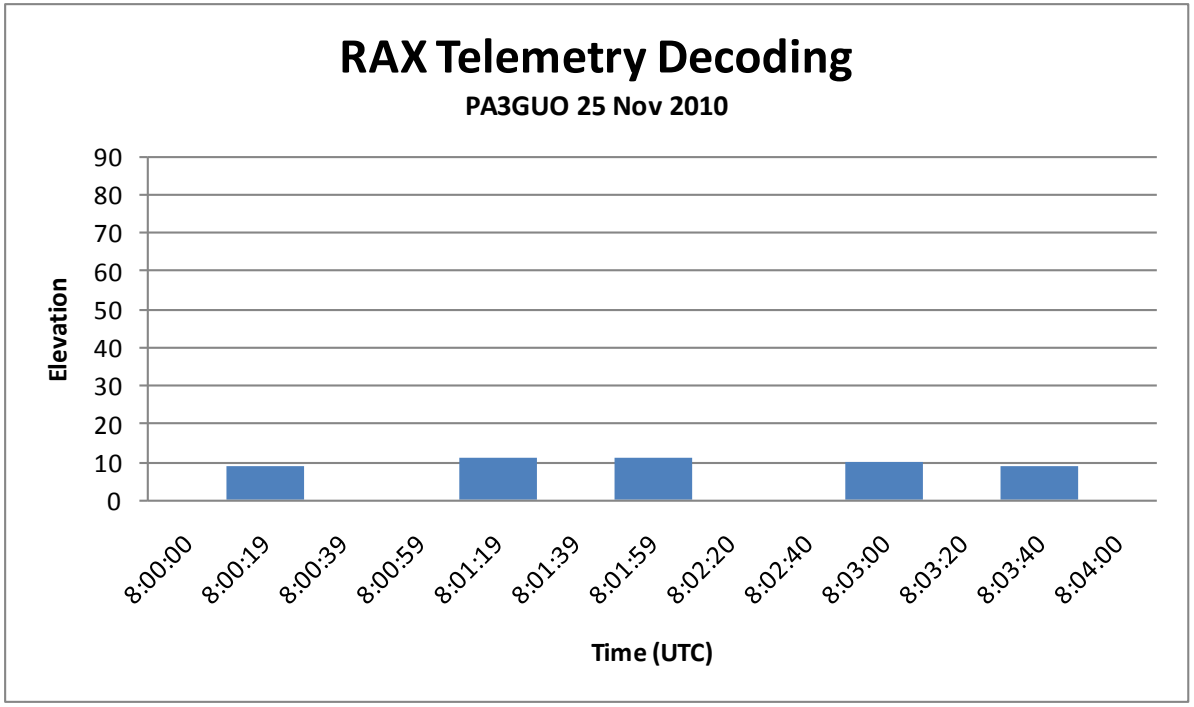
Analysis – 06:20 UTC pass



Maximum elevation	40
Pass duration	7 minutes
Transmitted packets	23
Decoded packets	21
Missed packets	2
Effectiveness	91%

Decoding threshold: 15˚ elevation
Medium elevation pass ➔ 91% decoded

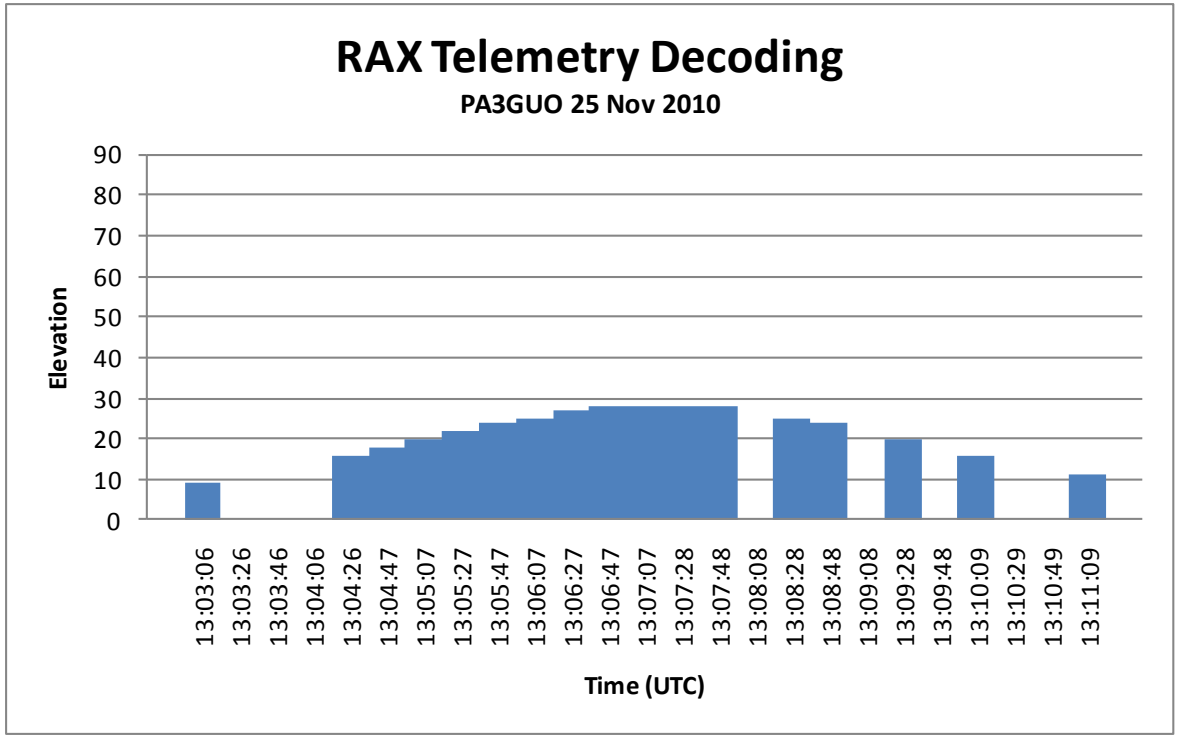
Analysis – 08:00 UTC pass



Maximum elevation	11
Pass duration	4 minutes
Transmitted packets	11
Decoded packets	5
Missed packets	6
Effectiveness	45%

Decoding threshold: 9˚ elevation
Low elevation pass ➔ 45% decoded

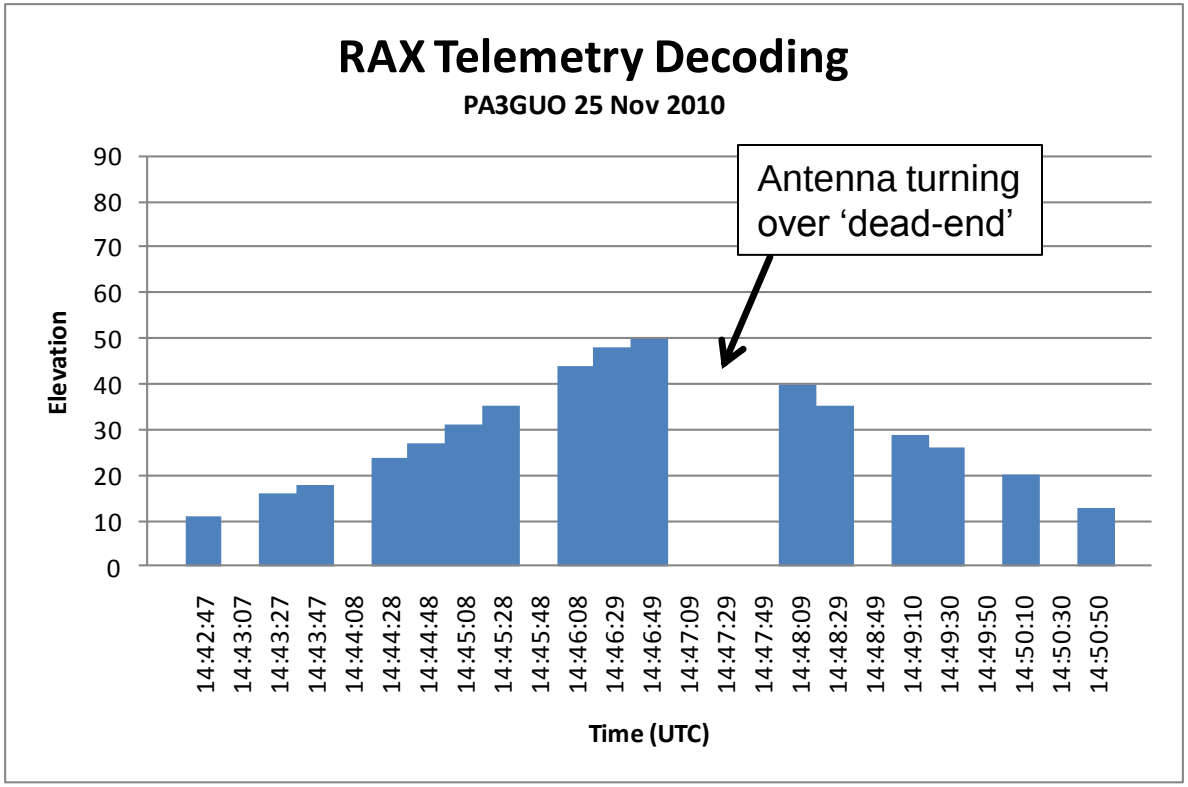
Analysis – 13:05 UTC pass



Maximum elevation	28
Pass duration	9 minutes
Transmitted packets	25
Decoded packets	17
Missed packets	8
Effectiveness	68%

Decoding threshold: 9˚ elevation
Low elevation pass ➔ 68% decoded

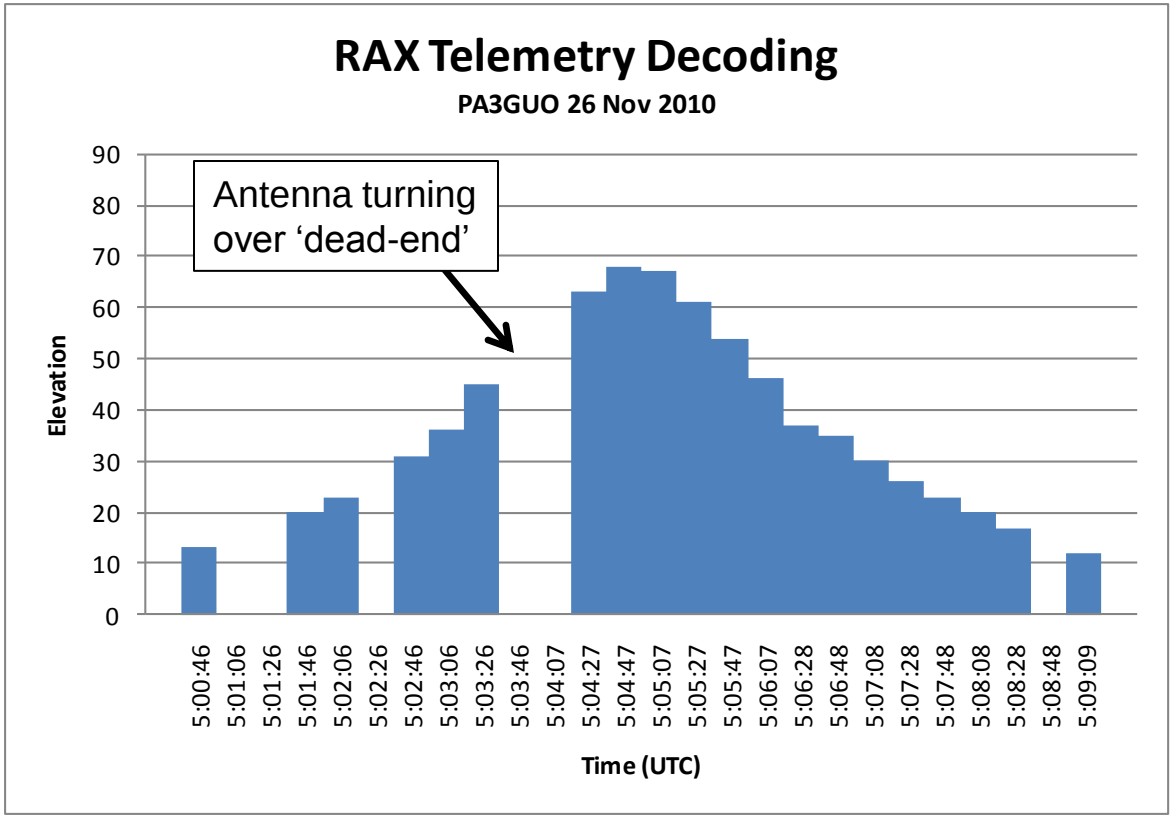
Analysis – 14:45 UTC pass



Maximum elevation	52
Pass duration	9 minutes
Transmitted packets	25
Decoded packets	16
Missed packets	9
Effectiveness	64%

Decoding threshold: 11˚ elevation
Medium elevation pass ➔ 64% decoded
When compensated for antenna turning: 72%

Analysis – 05:05 UTC pass

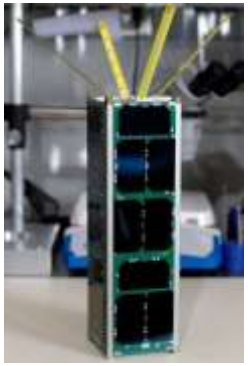


Maximum elevation	68
Pass duration	9 minutes
Transmitted packets	26
Decoded packets	20
Missed packets	6
Effectiveness	77%

Decoding threshold: 12˚ elevation
High elevation pass ➔ 77% decoded
When compensated for antenna turning: 85%

Analysis - summary

- Decoding threshold is ~10˚ elevation



- Decoding effectiveness:

06:20utc	40˚ elevation	91%
08:00utc	11˚ elevation	45%
13:05utc	28˚ elevation	68%
14:45utc	52˚ elevation	72%
05:05utc	68˚ elevation	85%

- Decoding low elevation passes: ~55%
- Decoding med/high elevation passes: ~85%

- 24 hours: 80 packets decoded, 31 missed: 72%
  (when compensated for turning antenna: 77%)

Conclusions

- Radio Amateur satellite ground stations can contribute to space research and science missions
- Ground Stations (GS) can be made with relative simple, 12 elements, directional antennas
- In 24 hours 80 telemetry data packets were downloaded
- During medium and high elevation passes a ground station can achieve >85% ‘RAX decoding effectiveness’

END