Spacecraft 1964 83D telemetry

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Introduction

Spacecraft 1964 83D is the oldest spacecraft in orbit that is still transmitting. This paper takes a look at its 136 MHz telemetry signal and tries to make some sense of it. The present and similar past telemetry are examined and the relationship between the various data rates is determined.

The spacecraft

The US Air Force launched two US Navy spacecraft under the code name OPS 6582 on a Thor Ablestar rocket from Vandenberg AFB into a 90° polar orbit on 13 December 1964 at 0014 UTC. NORAD cataloged the following objects from the launch[1-2]:

International Identification	Catalog Number	Description
1964 83 A	953	Ablestar second stage booster
1964 83 B	956	Fragment
1964 83 C	959	OPS-6582 (TRANSIT 5E-5)
1964 83 D	965	OPS-6582 (TRANSIT 5B-5)
1964 83 E-R	various	13 Fragments, 5 decayed

1964 83C Description: More widely known as 5E-5, the scientific objectives of this USN Applied Physics Laboratory (APL) spacecraft were to accurately map the earth's magnetic field over the regions covered by the satellite orbit, to map the celestial sphere in the ultraviolet region, to study the solar spectrum, and to determine the sublimation rates of selected metals. This magnetically aligned and polar-orbiting spacecraft was powered with solar cells and nickel-cadmium batteries. There were three transmitters; two were used for Doppler tracking on 162 and 324 MHz. The third was used for the transmission of analog and digital data on 136.650 MHz. The digital data were transmitted at 195 bps. Only real-time data were acquired from the satellite. Because of power limitations, it was necessary to switch the power from experiment to experiment and to the Doppler navigational transmitters with the experiments turned off. The satellite provided good quality data until June 1965[3].

1964 83D Description: Although known as Transit 5B-5 or even 5BN-5, this spacecraft should be called Oscar 2 or NNS 30020[4]. This Navy Navigational Satellite System Operational spacecraft was built by the Naval Avionics Facility at Indianapolis (NAFI) to the APL design and specifications[5-7]. The polar-orbiting spacecraft was gravity gradient stabilized and powered by solar cells and nickel-cadmium batteries. There were two transmitters; one each on 150 and 400 MHz that were used for geographic position location by users and for orbit determination by the TRANET network. Both were phase modulated with the 50 bps navigation message which broadcast the spacecraft ephemeris. The spacecraft provided housekeeping telemetry only upon command over USN ground stations by temporarily replacing the navigation message on the 150 MHz Doppler transmitter. The navigation transmitters failed on 31 December 1964 after just 19 days operation.

An additional 136.65 MHz telemetry transmitter, associated with this spacecraft, operates when the spacecraft is in sunlight.

The present telemetry

The 1964 83D telemetry transmission on 136.65 MHz is phase modulated by a combination of two sub carriers, one with analog Pulse Amplitude Modulation (PAM) data and the other with digital Pulse Code Modulation (PCM) data. The signal can be demodulated with a SDR-14 receiver and SpectraVue software using a 30 kHz bandwidth FM demodulator. The resultant file was analyzed and visualized with Spectrogram and Analyze 2000 software [Audio file 1].

The analog PAM sub carrier frequency varies between 4.9 and 6 kHz. This sub carrier is modulated by a 35 segment PAM commutator. 34 segments are about 0.33 seconds in duration and are 75% data and 25% return to near centre frequency. One other segment is longer in duration (1.32 seconds) and is probably the start of frame indicator. The assignment of the segments is not known but the 9th segment is a sub-commutation of "tell-tale" digital indicators. These are 50% duty cycle with a 'one' as a half height pulse and a 'zero' as a full height pulse. These would be for indications of launch vehicle separation, solar panel blade erection, satellite de-spun, gravity gradient boom deployed and electro-magnet on/off. Faulty segments 34 and 35 extend to about 8 kHz. See Figure 2. Each 35 segment frame of the current telemetry takes about 12.45 seconds. Using a 1973 telemetry recording [Audio file 2], the earlier PAM telemetry period was determined using Spectrogram software to be 24.9 seconds or twice the period of the present telemetry.

The digital PCM sub carrier toggles between 9.9 and 11.3 kHz. Using the Analyzer 2000 software and its FSK demodulator, the data rate has been determined to be about 389 bps with each 256 bit block (data and gap) taking 0.65 seconds. This also corresponds to two PAM segment durations so there are 19 PCM blocks per PAM frame. In Figures 3 and 4, the PCM data shows some structure but it fairly random with some data missing due to now faulty multiplex logic.

Previous similar telemetry

136 MHz PAM analog commutator with 256 bit PCM digital encoders were flown on several APL spacecraft. These include 1961 αη-2 (TRAAC), 1963 38C (5E-1), 1963 49C (5E-3), 5E-2 which failed to orbit and 1964 83C (5E-5) [8].

1964-38C (5E-1) had a 136 MHz telemetry transmitter with PAM and PCM sub-carriers oscillators similar to the present telemetry. The PAM was used for housekeeping and science data while the PCM was used for the charged particle detector experiments and digitized PAM data[9]. The telemetry was the linear combination of two sub-carrier oscillator outputs that phase modulate (±1 radian) a radio frequency carrier of 136.65 MHz at 0.75 Watt. A 10,500 Hz sub-carrier oscillator was connected to a 256 bit digital encoder whose data was continuously shifted out at about 195.3 bps. It consists of a 16 bit sync word, a 16-bit frame counter and 14 data words of 16-bit each. A 5,400 Hz sub-carrier oscillator was connected to a 35 channel PAM commutator. A similar system was also used on 1964-83C (5E-5) which carried a Rb^{85} vapor magnetometer experiment[10]. A 35 segment commutator showing the use of the 'tell-tales' in segment 9 was used on the APL-built Beacon Explorer XXII and XXVII spacecraft[11].

Telemetry data rate relationships

The Oscar telemetry data rates are all related to a near 5 MHz high stability (a few parts in 10^{-11}) temperature controlled quartz crystal oscillator that was offset by -80 parts per million, i.e. 5,000,000 Hz – 5 x 80 ppm = 4,999,600 Hz. This was then multiplied up to the two Doppler navigation transmissions of 149.988 and 399.968 MHz.

The navigation message[12] was 6103 bits repeating every 2 minutes giving a message bit period of 19.662 ms or 50.858 Hz, i.e. 4,999,600 Hz divided by 3 x 32,768.

For the PCM telemetry, 4,999,600 Hz divided by 51,200 is 97.648 Hz or 195.297 bps.

For the PAM telemetry, 4,999,600 Hz divided by 3,276,800 gives 1.526 Hz or 655.412 milliseconds dwell time per segment. As there are actually 38 periods in each frame (4 periods for segment 1 plus the other 34 segments), this means that a complete frame takes 24.906 seconds.

Note that 256 bits at 195.3 bps takes 1.311 seconds which is two PAM channel durations so there 19 groups of 256 bit PCM data per PAM frame.

Discussion

I have not received any telemetry on 136.65 MHz from 1964-83C and assume that there has not been any since 1965. There are no indications of 136 MHz telemetry systems on any other Oscar spacecraft. Perhaps the 136 MHz telemetry system was added to 1964-83D after the premature failure of Oscar-1 to provide additional engineering data or to get extra support from NASA's world wide ground stations[6].

It is quite remarkable that 1964-83D is still transmitting. Given the right sunlight conditions, the signal strength is sufficient to 'fully quiet' a FM demodulator for some of a pass with both sub-carriers present.

The telemetry data is meaningless but it does show that some parts of the spacecraft are still functional; one or more solar panels, a clock oscillator, the commutators, the sub-carriers oscillators, the phase modulator and RF transmitter. They made 'things' to last back then!!

It is interesting that the data rate of the present telemetry is twice as fast as designed, perhaps a divided by 2 counter 'shorted out' sometime after 1973!

I have not been able to find any description of the current telemetry. It would have been much easier if 1964-83C and D had been mislabeled by NORAD so that 1964-83D was actually 5E-5 that did have an announced 136.65 MHz transmitter but this is highly unlikely to have occurred.

Have a listen to 1964-83D while it is still the oldest transmitting spacecraft in orbit, what ever it is called.

References Links last accessed April 2010.

1. RAE Tables of Earth Satellites, 1964
   http://www.home.zonnet.nl/leobarhorst/RAE/RAE1964.doc

2. Space Track->Search by Launch date or International ID, 1964, Launch Number 83, All
   http://www.space-track.org

3. National Space Science Data Centre.
   http://nssdc.gsfc.nasa.gov/nmc/spacecraftDisplay.do?id=1964-083C

4. An Overview of the Navy Navigation Satellite System
   Johns Hopkins University Applied Physics Laboratory
   http://sd-www.jhuapl.edu/Transit/

5. NNS Transit-O spacecraft.
   http://www.skyrocket.de/space/doc_sdat/transit-o.htm

6. Encyclopedia Astronautica, Transit Program
   http://www.astronautix.com/craft/transit.htm

7. An overview of Transit Development, R. J. Danchik,
   Johns Hopkins University APL Technical Digest, Volume 19, Number 1, 1998
   http://www.jhuapl.edu/techdigest/td1901/danchik.pdf

8. Artificial Satellites designed and fabricated by the John Hopkins University Applied Physics Laboratory, SDO 1600, July 1978. DTIC ADA066299

9. Description of Satellite 1963-38C and Charged Particle detectors – Problems with data reduction, Semiannual report period ending September 30 1965,
JHU APL TS 1125 October 1965. NTRS 19660004280
10. The 5E-5 Rubidium-85 Vapor Magnetometer, W. E. Radford,
JHU APL Technical Memorandum TG 890, February 1967. NTIS AD652807

11. Polar Ionosphere Beacon Satellite, S-66, Operations Plan 2-63.
NASA GSFC, 1963 NTRS 19640015076

12. The Transit Navigation Satellite System, T. A. Stansell, Magnavox, 1978.

Audio files

1. 1964-83D 136.65 MHz telemetry, Mike Kenny, April 2010.
http://mdkenny.customer.netspace.net.au/1964-83d.mp3 (60 sec, 960 KB)

2. 1964-83D 136 MHz telemetry, Greg Roberts, 1973.
http://www.dd1us.de/sounds/1964-083d.mp3

Software

1. SDR-14 receiver, http://www.rfspace.com/RFSPACE/SDR-14.html

2. SpectraVue, http://www.moetronix.com

3. Spectrogram, seems to be no longer supported or available.

4. Analyzer 2000, http://www.brownbear.de/toc.htm

Appendix

On 31 December 1996, the NNSS ceased operation as it had been superseded by the NAVSTAR Global Positioning System. The NNSS then became the Navy Ionosphere Monitoring System (NIMS) that uses satellites to derive values of Total Electron Content (TEC) of the ionosphere through computerized ionospheric tomography (CIT) techniques[A1]. The navigation message was replaced with a null message on the 400 MHz transmitter and by spacecraft telemetry on the 150 MHz transmitter[A2]. The PAM/FM/PM telemetry is a 35 segment commutation on a 2300 Hz sub carrier and is very similar in structure to the present telemetry from 1964-83D[A3].

As of May 2010, 1988-33A, Oscar-23 and 1988-74A, Oscar-25 are the last of the NNSS spacecraft still transmitting on 149.988 MHz[A4].

A1. http://www.jhuapl.edu/techdigest/td1901/tucker.pdf

A2. http://sgl.arlut.utexas.edu/research/transit.html

A3. 1988-74A, Oscar-25 149.988 MHz telemetry, Mike Kenny, April 2010.
http://mdkenny.customer.netspace.net.au/1988-74a.mp3 (60 sec, 960 KB)

A4. http://maestro.haarp.alaska.edu/cgi-bin/its10/plot-tec.cgi

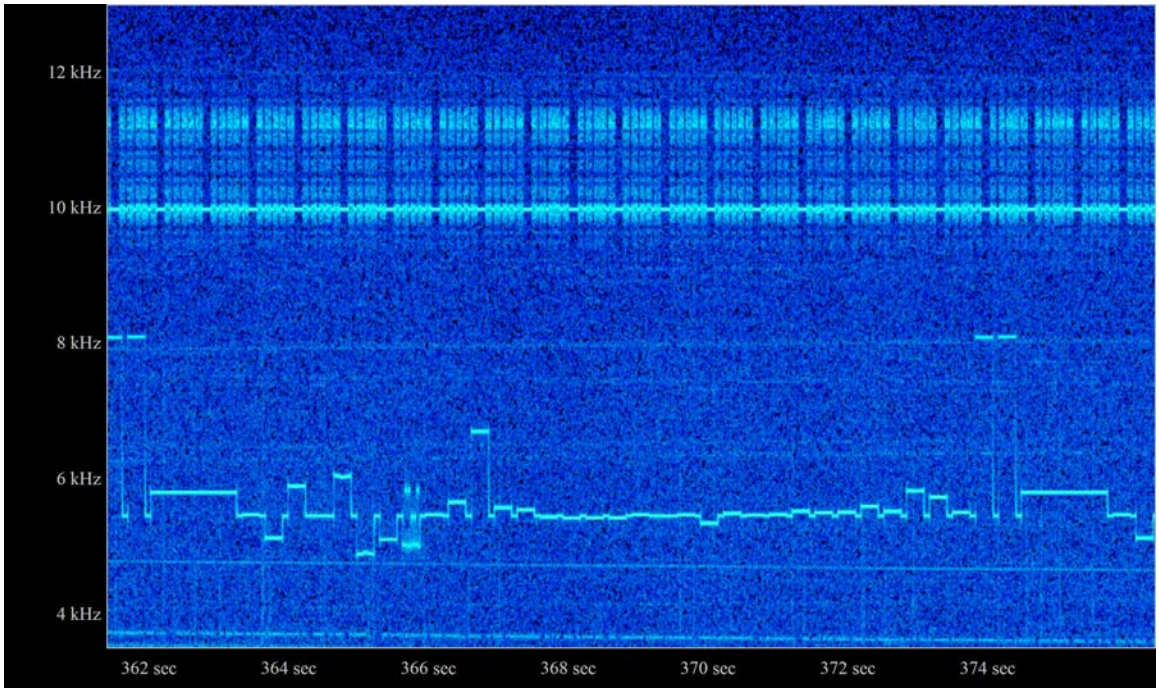

Figure 1 1964-83D PAM (lower trace) and PCM (upper trace) telemetry

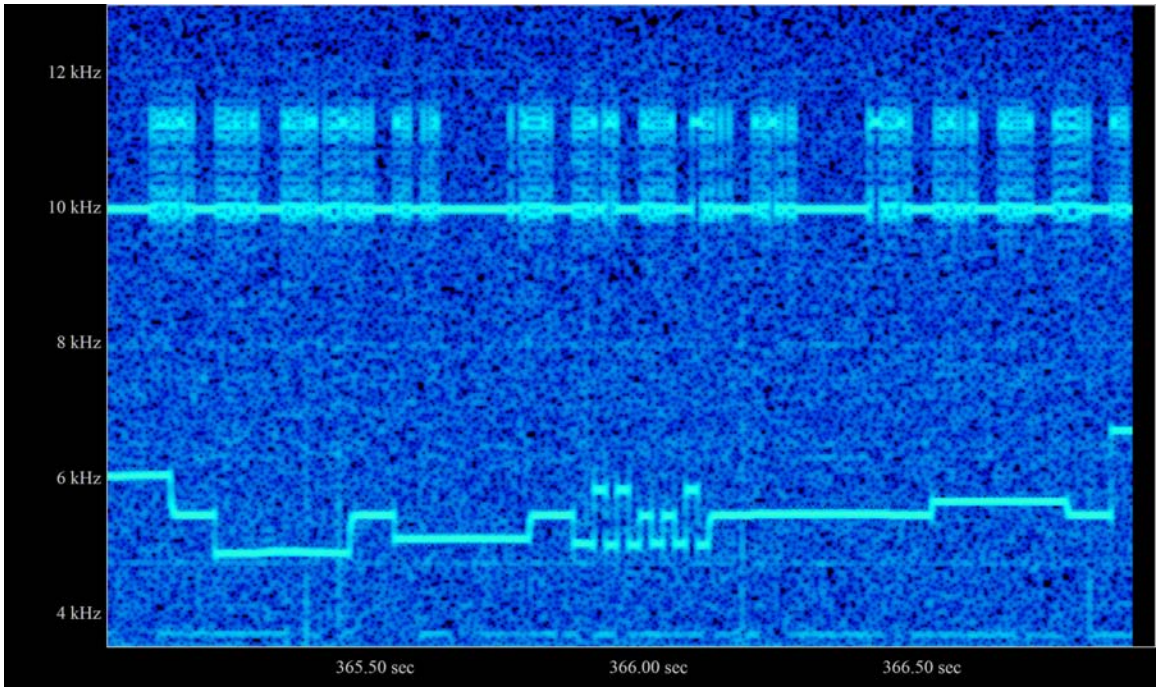

Figure 2 1964-83D telemetry segment 9 'tell-tales' (middle of lower trace)

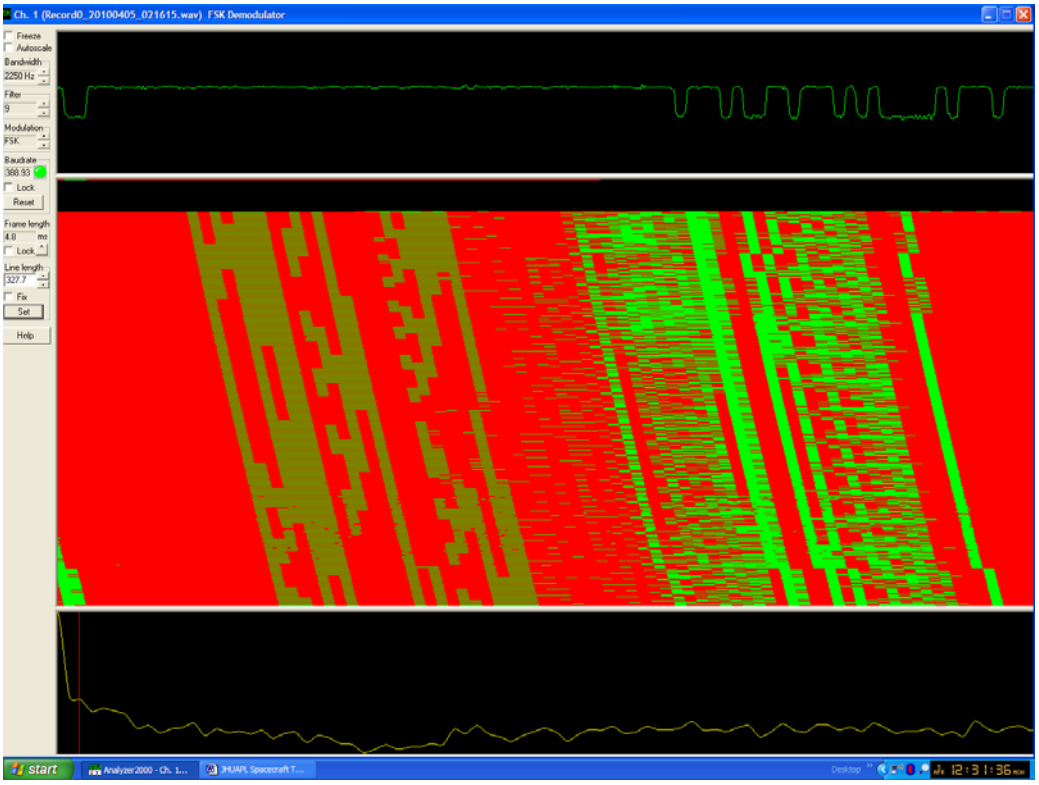

Figure 3 1964-83D PCM telemetry demodulated with Analyzer 2000

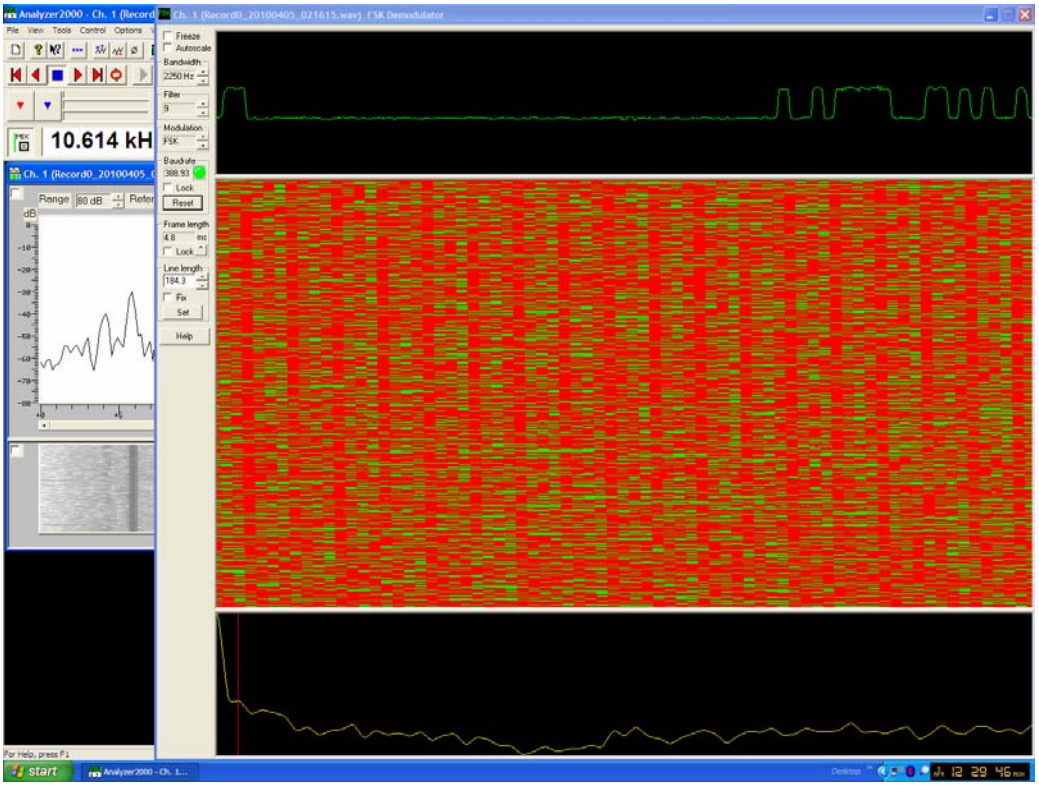

Figure 4 1964-83D PCM telemetry demodulated with Analyze 2000