IRIG 106 CHAPTER 10 DECODER FOR KSLV-II TELEMETRY DATA ANALYSIS

Taejin Lee[1], Chunwon Kim[1], Jin-A Ma[1], Soonho Kwon[1], Dong-hyun Kim[1]

[1]Flight Safety Technology Division, Naro Space Center
Korea Aerospace Research Institute, Republic of Korea

ABSTRACT

NARO Space Center has established telemetry ground stations comply with the Inter-Range Instrumentation Group (IRIG) 106 standard [1] for the Korea Space Launch Vehicle-II (KSLV-II, Nuri). Among these, the Safran Radio Signal Recorder (RSR) is employed to record the data associated with the launch mission. The RSR is capable of recording and replaying a multitude of input sources, including IF (intermediate frequency), AGC (automatic gain control), PCM, and IRIG-B. All data is recorded in the Chapter 10 (.ch10) format in accordance with the IRIG standard. For subsequent analysis, the recorded files can be playback in the RSR. However, it is also possible to decode the Chapter 10 files for research purposes, such as the analysis of RF channel characteristics and PCM raw data. In this paper, we used IRIG open software and MATLAB to decode the telemetry data in the Chapter 10 file and present the results.

Keyword: IRIG-106, TELEMETRY RECORDER, CHAPTER10, DECODER, KSLV-II

1. INTRODUCTION

The telemetry receiver at the Naro Space Center receives real-time status and video streams of each stage of the launch vehicle and records the IF, AGC signals and various data (PCM, IRIG-B) using RSR. The stored signals can be replayed for detailed analysis after the launch mission. This allows for the reproduction of the received conditions and environment at the time of the mission, which can be input to the telemetry receiver. In other words, while general DAQ (data acquisition) equipment is designed to record specific signals, the telemetry recorder is intended to provide a comprehensive solution for various types of telemetry data, including AGC signals, PCM data, and time information (IRIG-B) of the receiver, as well as received RF/IF signals. The key specifications of the RSR are presented in the following table.

Figure 1. Telemetry System and Recorder

Figure 2. Safran's Telemetry Recorder (RSR-IF)

Table 1. Specifications of telemetry recorder (Safran, RSR-IF)

IF		PCM	
Channel	4 Channel	Channel	8 Channel
Center Frequency	66 ~ 74 MHz	Bit Rate	1 kbps ~ 40 Mbps
Bandwidth	0.625 ~ 40 MHz	Interface	TTL / RS-422
Level	-10 ~ +5 dBm		
Sample Rate	2.5 x BW	PCM Code	NRZ-L/M/S Bi-phase L/M/S
Quantization Bits	8 / 16 bits		
AGC		Time & Synchronization	
Channel	4 Channel	IRIG Timecode	IRIG-B122
Bandwidth	50 kHz	1PPS	LVTTL 50Ω
Level	±5V	Ext. Ref.	10 MHz

2. Application of the Chapter 10 Decoder

The RSR is based on the Windows operating system, and the received telemetry data is recorded as a binary file in the Chapter 10 (.ch10) format. In this file, the TeleMetry Attributes Transfer Standard (TMATS) attribute information is recorded first. TMATS describes the key attribute information needed to exchange telemetry data between telemetry devices. RSR's TMATS information encompasses three categories: general information (Group G), recorder information (Group R), and manufacturer information (Group V). The general information includes the file name, standard version, creation date, and test section. The recorder information consists of the storage media type, recorder manufacturer, model name, storage channel, data rate, and sampling rate. Finally, the manufacturer information includes the manufacturer's name and contact information. To access these details, it is possible to decode the XML (eXtensible Markup Language) Schema in the Chapter 10 file directly. However, due to its extensive content, it is recommended to use the TMATS open software provided by IRIG. This software is igDisplayTMATS [2], which allows the user to view relevant TMATS information in raw data, summarized information, and tree form.

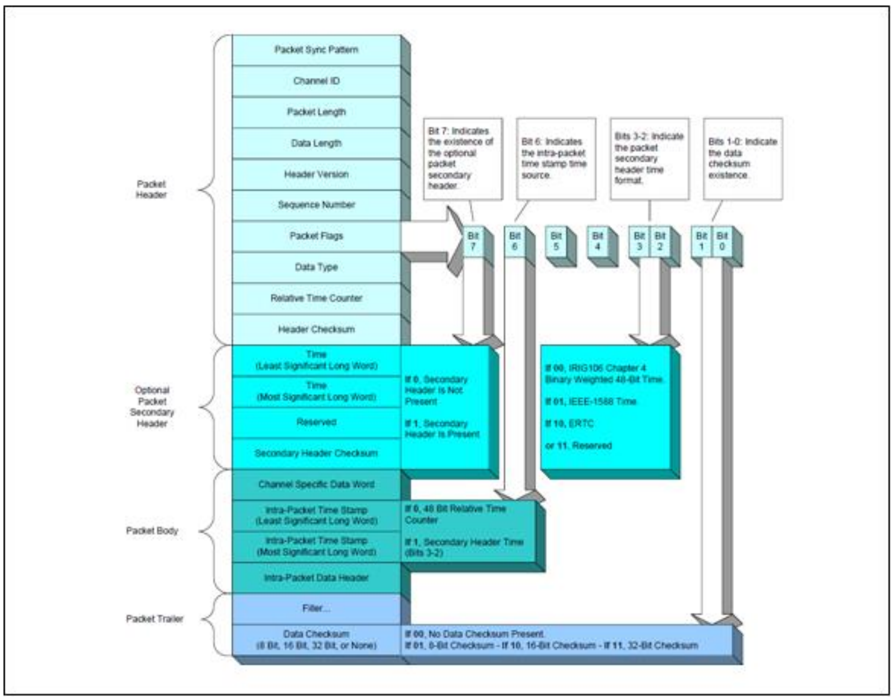

Figure 3. Structure of Chapter 10 Packet

In the Chapter 10 file, the TMATS information is followed by the actual data packets. All packets adhere to the Packet Format Standard described in the IRIG-106 standard, and the structure of the packets is depicted in Figure 3. The Packet Sync Pattern (0xEB25) indicates the start of the packet and allows the user to determine the location of the packet. While the synchronization pattern is readily detectable within the file, the classification of the various packet types and their respective channels for the entirety of the Chapter 10 file, which is typically a huge data, need more considerably effort. In this instance, the header extraction software provided by IRIG, igDmpHeaders [2], was employed to facilitate this process. This approach allows for the categorization of all packet headers, irrespective of the IRIG standard version of the Chapter 10 file, and the subsequent classification of the location, length, channel, and other information associated with the packets within the file. To extract the data associated with each packet based on the header information, MATLAB-based decoder was employed. Given the considerable volume of data, the code was designed to select and extract only the data sets (IF, AGC, PCM) for specific channels. In this case, each packet can be accessed by separating the packet header (40 bytes) to gain access to the actual data. However, it should be noted that analog data has different sampling rates depending on the channel settings, as illustrated in Table 2. This should be considered when handling time series data.

Table 2. Configuration of analog channel in the telemetry recorder

	IF	AGC	IRIG
Sampling Rate	0.78125 ~ 50 MHz	360 kHz	195 kHz
Quantization Bits	8 / 16 bits	16 bits	16 bits
Channels	4 x 2 Subchannel (I/Q)	4 Channel	1 Channel

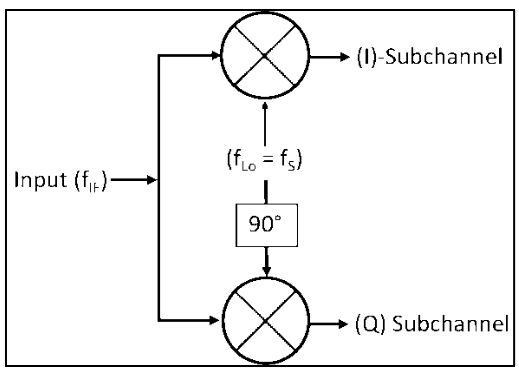

Figure 4. Down-conversion of IF signal in recorder

As illustrated in Figure 4, the IF signal with a center frequency of 70 MHz is divided into I/Q (in-phase, quadrature-phase) signals and converted to baseband simultaneously. This is in accordance with the recently established Analog Data Packets - Format 3 in IRIG 106-22, which specifies that two subchannel (I/Q) samples are stored in alternating 8-bit (or 16-bit) increments in one IF packet. The advantage of this format is that it allows for lower data rates when storing data. However, it should be noted that distortion of the signal may occur during down/up conversion due to the IF signal passing through the analog circuit. Consequently, RSR compensates for the distortion by implementing an equalizer to minimize the distortion of the signal. In this case, PCM data is stored in "Throughput Mode" in RSR. This is the mode officially supported by the IRIG-106 standard and corresponds to the case where the telemetry receiver does not perform frame synchronization. Consequently, in order to decode the PCM data stored in the Chapter 10 file, a frame synchronization must be conducted separately in order to obtain valid data. Furthermore, it is essential to ascertain the compatibility of Chapter 10 files in accordance with the RSR version, as the order of data storage differs between the 16-Bit alignment mode and the 32-Bit alignment mode, even within the same throughput mode.

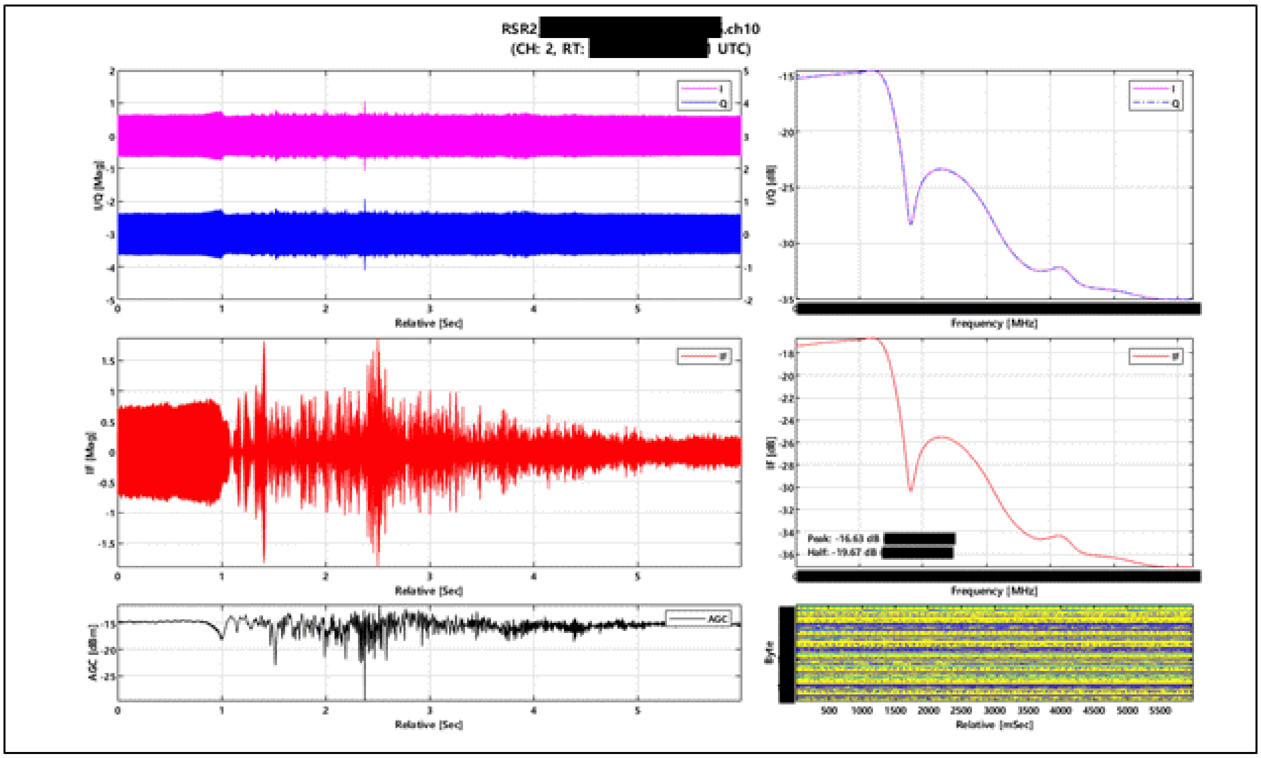

Figure 5. Visualized decoded result of recorded chapter 10 data

Figure 5 illustrates the decoded results of telemetry data from an actual Chapter 10 file. The figure begins with a display of the time series data for the I/Q signals and the characteristics of the I/Q signals in the frequency domain. This is followed by a representation of the IF signal in the baseband, which was generated by synthesizing the I/Q signals. The modulation scheme employed is PCM/FM, which allows for the observation of the spectral characteristics of the PCM/FM in the baseband. In particular, the generated IF signal can be utilized for AGC data analysis to assess the time-varying characteristics of the IF signal. The time series data of the AGC signal can be observed in the lower portion of the left. In the case of AGC, the IF level in the range of -110 to -10 dBm is scaled by 16 bits, necessitating a separate conversion process. Finally, the received PCM data is shown on the bottom right. Since the PCM data has been frame synchronized through the MATLAB code, it can be seen that certain patterns according to the frame structure are identified.

3. Mission Data Analysis

The launch pad of the NARO Space Center is situated in a valley terrain, with the sea on one side and mountains on the other. The terrain presents a number of challenges for the actual launch mission, including multi-path. The TLM1 ground station is responsible for the telemetry during the initial phase of the launch mission. The TLM0 unmanned small ground station, is operated in close to the launch pad in order to overcome the aforementioned environmental challenges. Each ground station is equipped with an individual receiver and data processing system. Through the best signal selector at TLM1 ground station, the optimal data from each ground station can be transmitted to the Mission Control Center.

Figure 6. KSLV-II 2nd Launch (Drone view)

To verify the data received from the actual launch mission, we employed the Chapter 10 Decoder previously described. The launch mission was the KSLV-II 2nd launch on June 21, 2022 (H0: 172:07:00), and the analysis found one minor frame CRC error in the lift-off phase during the mission. This error is believed to have been caused by a momentary degradation of the radio frequency (RF) channel due to the release of liquid oxygen from the separation of the umbilical tower shortly after liftoff and the scattering of ice surrounding the launch vehicle. In contrast, the TLM0 ground station was able to receive the signals normally. A comparison of the PCM data from TLM0 with TLM1 revealed a total of 17 bits of error. The IRIG-B time on the minor frame where the error occurred was between 07:00:01.3792s and 07:00:01.3817s. The telemetry signal from the launch vehicle is in the S-band and is transmitted in linear polarization through antennas placed on either side of the launch vehicle. The receiver at the TLM1 ground station demodulated the combined Pred signal using polarization diversity techniques, but as shown in the analysis above, errors were introduced. Although the error rate was relatively low, it is meaningful information for future improvement of receiving performance.

Figure 7. KSLV-II 2nd Launch (June 21, 07:00:01.38 UTC)

4. CONCLUSION

In this paper, we present the telemetry recorder applied to the telemetry system at the NARO Space Center and the decoding method and results of the recorded data. Unlike general data acquisition (DAQ) equipment, telemetry recorders support various input formats according to telemetry standards and are designed to maximize compatibility between telemetry equipment.

However, due to its unique format, it was difficult to access the recorded data. Consequently, we employ IRIG open software and a MATLAB-based decoder program. This approach enables not only the verification of the recorded status of IF, AGC, and other parameters but also the retrieval of the PCM raw data. It is expected that the application of this decoder will be extended to research applications such as the extraction of RF characteristics from the recorded IF signal.

REFERENCES

[1] Range Commanders Council, IRIG STANDARD 106-22, TELEMETRY STANDARD

[2] IRIG 106 wiki / Software and Utilities, Oct 2022 (https://irig106.org/wiki/software_download)