A STUDY OF DATA PACKETING FOR K3 X-BAND CHANNEL

JongTae Lee, SangGyu Lee, SangTaek Lee, Sang-Soon Yong

Korea Aerospace Research Institute, jtlee@kari.re.kr

ABSTRACT: For the space communication between a satellite and a ground station, spacecraft performs data packeting and data coding. Using standard format certainly has an advantage but depending on the hardware implementation sometimes compliance with the standard is hard to accomplish. This paper studies the suitable way to transfer image data and ancillary data to the ground station in the format of CCSDS recommendation.

KEY WORDS: Ancillary, Image, X-band, CCSDS, Packetizing

1. INTRODUCTION

The Consultative Committee for Space Data Systems (CCSDS) is an organisation officially established by the management of member space agencies. The CCSDS recommendation establishes a common framework and provides a common basis for the data structures of spacecraft telemetry streams. It is also possible to make and use special data frame format for the project. But new definition of data field needs more efforts to make understood both space and ground segments and has propensity to a mistake. In case of the configuration of the satellite is not a condition to implement the recommendation, modification of the recommendation is better way than create another format.

The CCSDS recommendation assumes hierarchical data process on the payload. As illustrated on Figure 1. K-3 payload data handling is not follow an ideal steps. Instruments of K-3 payload generates image data stream with instrument header. Image compression is done inside the Image Data Handling Unit (IDHU) of payload data transmission system (PDTS). After compression, the image data is recorded to a memory system. Source packeting and Transfer framing functions are executed by same processor. The processor reads image data from the memory and performs source packeting and transfer framing. So practically there is no meaning of source packeting in the K-3 system. It's just for compatible packetization with CCSDS recommendation. Because the payload data can be downloaded by another ground station it helps image reception without any conflict. Transmission of transfer frame data is responsible for X-band transmitter. From this data is RF format.

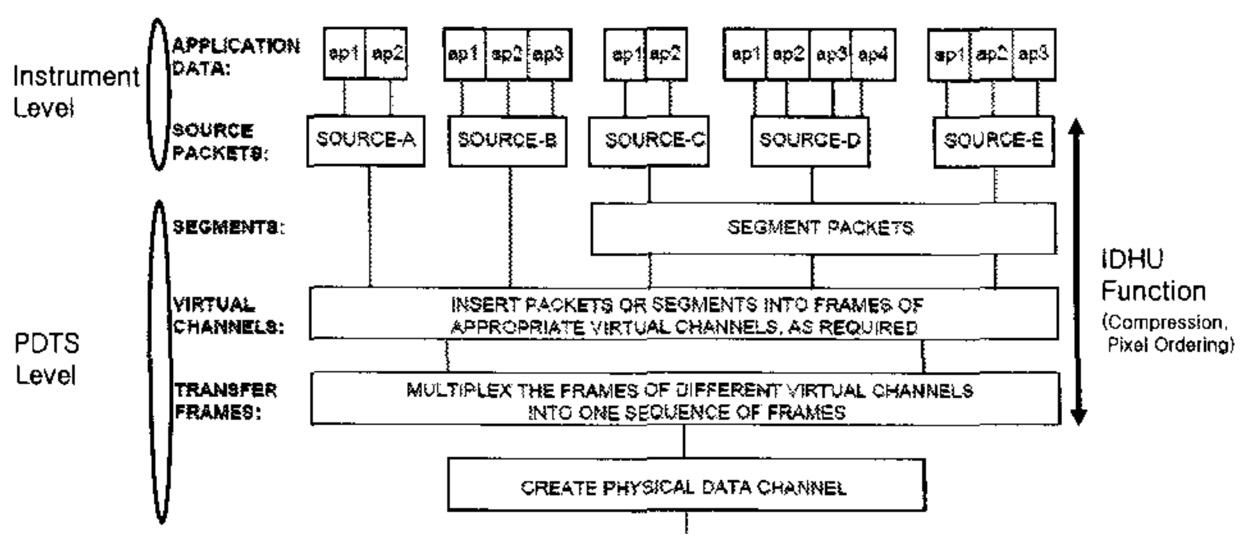

Figure 1. K3 Data Handling

2. K-3 TRANSFER FRAME

To organize the K-3 transfer frame following should be considered.

2.1 Ancillary Data Handling

Ancillary data is assistant data for the reconstruction of the imagery to enhance image quality by the Image Reception and Processing Element (IRPE). Ancillary data includes satellite attitude, attitude, location, and so on.

There are two kind of ancillary data. One is from Camera Electronics Unit (CEU) which holds internal configuration, line counter, CCD temperature, etc. The other one is from Integrate Bus Management Unit (IBMU) which is IBMU gathered information from spacecraft subsystems such as spacecraft time, GPS time, orbit data, satellite control mode and so on. The CEU ancillary will be inserted by the CEU itself into a image header. The IBMU ancillary data will be inserted by the IDHU. The IDHU receives IBMU ancillary data through 1553B interface during imaging mission only.

One possible way to transmit the ancillary data is recording it as a separate file and downloading the data when the ground station requests it. Ancillary data can be downloaded immediately after the finishing transmission of images. It's relatively small size. Ancillary data has a time tag and image data also has a time mark, the ground station has no difficulty on image processing.

The other way is the sending ancillary data with image data which is the decision of K-3 ground station. This method doesn't need additional file creation and the ground station already has a heritage from the K-2.

<table>
<tr><th rowspan="2">SOH</th><th colspan="2">Image Data Header</th><th rowspan="2">SOI</th><th rowspan="2">Image Data</th><th rowspan="2">CRC</th><th rowspan="2">EOI</th></tr>
<tr><th>CEU Ancillary (36 bytes)</th><th>IBMU Ancillary (4 bytes)</th></tr>
<tr><td colspan="7">1 Line Data</td></tr>
</table>

- SOF : Start Of File (2 bytes)
- SOH : Start Of Header (2 bytes)
- SOI : Start Of Image (2 bytes)
- EOI : End Of Image (2 bytes)
- EOF : End Of Image (2 bytes)

Figure 2. Ancillary Data Insertion

The IDHU inserts IBMU ancillary data at the end of CEU ancillary data as shown in Figure 2. The CEU will make spare room in the CEU header, so that the IDHU can easily insert IBMU data without making timing slot in the image stream. Total 512 bytes of IBMU ancillary data will transfer to the IDHU every second. The IDHU takes 4 bytes of IBMU data sequentially and inserts them to the end of CEU header. Normal line rate of CCD data is 9700 line/sec so IBMU ancillary data will be repeated some times and replayed by new ancillary table at the next pulse per second signal. There is no IBMU ancillary data ID for describing contents of the data but there is sync. pattern to represent this is the start of new IBMU ancillary data sequence every second. The ground station first detects the sync. pattern then decode rest data as defined sequentially.

There is an inherent delay of the ancillary data travelled from subsystem to the IDHU through IBMU. They are using common 1553B communication line to hand over the ancillary data. In order to receive the ancillary data of the last required video line mission planning on ground has to extend the imaging mission by two more seconds. Following abnormal cases of ancillary data insert should be taken into consideration. The first: during the first one second of transmission, undetermined bytes will be inserted in the ancillary data fields. The second: when the payload is operated at very low line rates, the IDHU is not able to insert all the ancillary data. The ancillary data is treated as image header. So it is not an object of compress but an object of RS coding for EDAC function.

2.2 Source Packet

The IDHU has to perform source packeting and transfer frame packeting at same time. To save the memory space by source packet header and hardware required to process source packeting, source packeting will be done at output interface board with the function of transfer frame formatting. Theorically the source packeting should be done by the instrument level but there is not enough physical space to put this function in the camera electronics. The IDHU performs source packeting virtually to fit for the CCSDS recommending format.

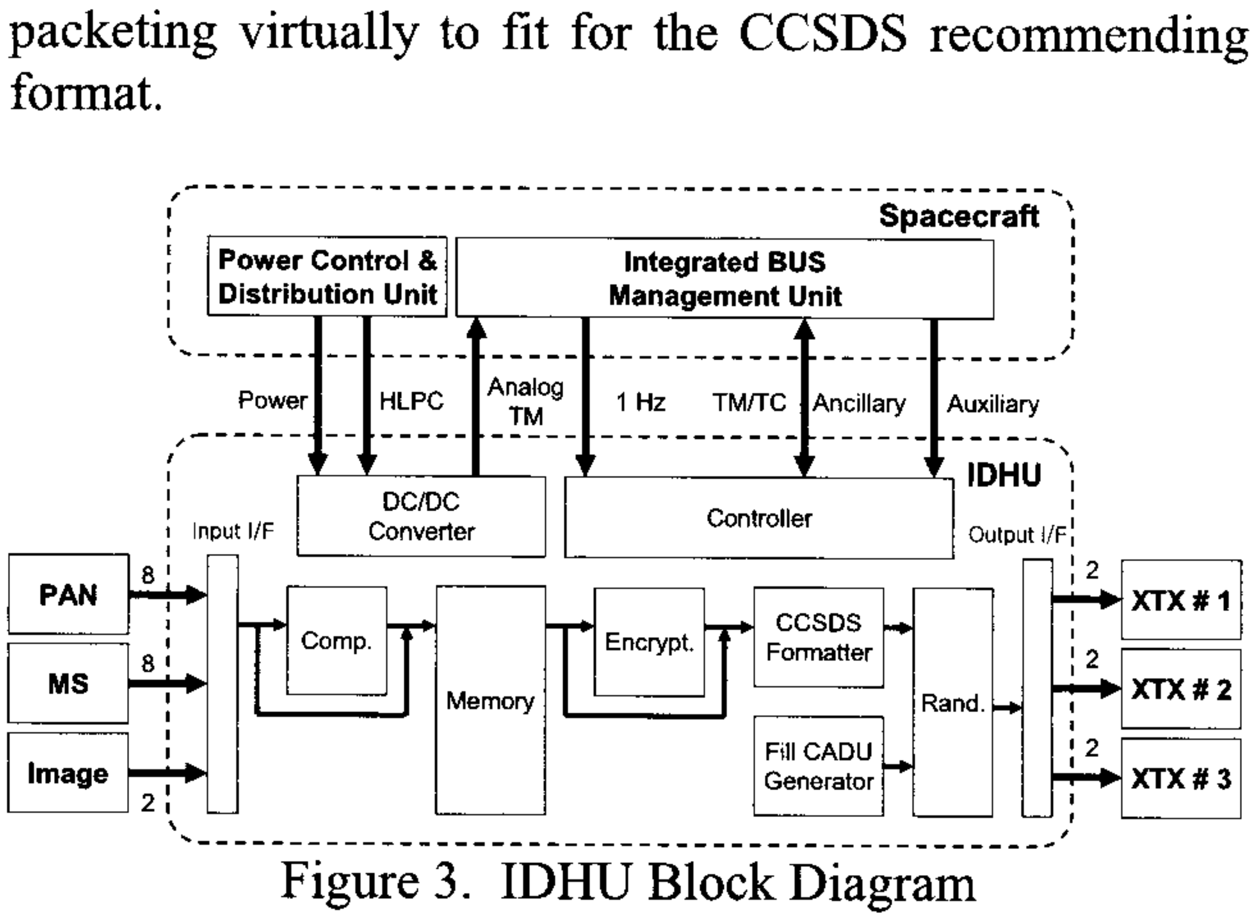

Figure 3. IDHU Block Diagram

In compression mode the IDHU will generate compression header which includes sync. pattern. The sync. pattern will be recorded in the memory. It makes easier for output interface board to find each start of new lines. In no compression mode the IDHU performs image data pixel to byte conversion by filling unused 2 bits of 2 bytes image data with 2 most significant bits of next pixel data. 14 bytes are required to store 8 pixels. Normally segmented source packeting with dedicated packet length can be used the send entire mission data to the ground station unless there is loss of transfer frame on the X-band transmission. But a problem breaks out because one of the IDHU requirements is performing replay partial file. The download starts not only at the beginning of a file but also can be anywhere of a file as shown in Figure 4. If the output interface board reads the data from the memory and send the data with source packet format on partial replay mission, the ground station can not detect a start of image line unless a memory segment which is the minimum size of the memory fits to record uncompressed one line. Changing memory segment size is not easy because there are PAN image data, MS image data and additional image data.

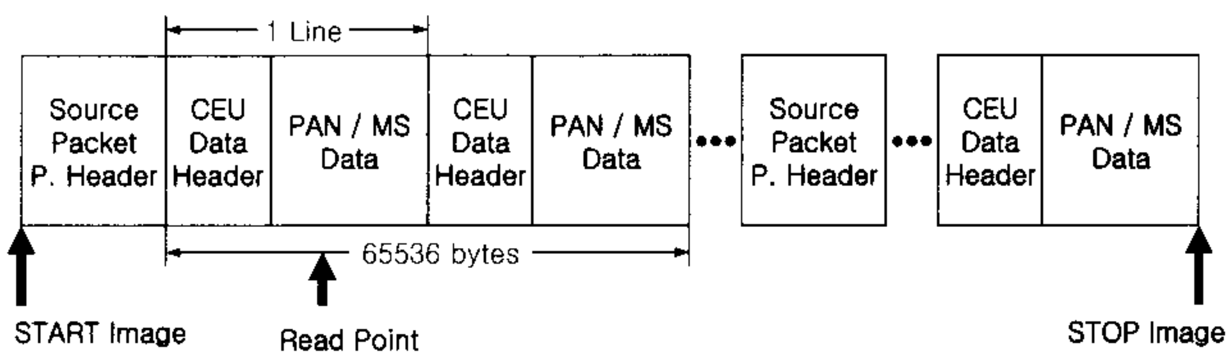

Figure 4. Erroneous Replay of Partial File

To cope with this problem the IDHU adds line sync. mark in front of each starting of new image line before recording image data to the memory at no compression mode. This line sync. mark is used only inside the IDHU and will not transfer to X-band channel on transfer frame data. The output interface board of the IDHU throws away the line sync. mark after the starting of source packeting. During partial file replay mission the output interface board will ignore any kinds of data from the memory before detecting the first line sync. mark. By this it is guaranteed the ground station always get image data from an image line at no compression mode. On the other hand, it means that depending on the requested read point of no compression replay mode, the contents of transfer frame data varies and the size of download data can be different with requested data size.

In case of auxiliary data which is playback data of Integrate Bus Management Unit (IBMU) mass memory, it is already CCSDS formatted by the IBMU before sending the auxiliary data to the IDHU. Although auxiliary data is inverted inside the IDHU, the ground station has no difficulty on decoding auxiliary data because it already has an attached sync. of transfer frame. No sync. mark is needed for auxiliary data transmission although only no compressed recording mission is available for auxiliary recording mission.

2.3 Transfer Frame Version

There are two recommended versions of CCSDS transfer frame to transmit payload data to the ground station. The first one is version-0, TM (Telemetry) Space Data Link Protocol. The second one is version-1, AOS (Advanced Orbiting System) Space Data Link Protocol.

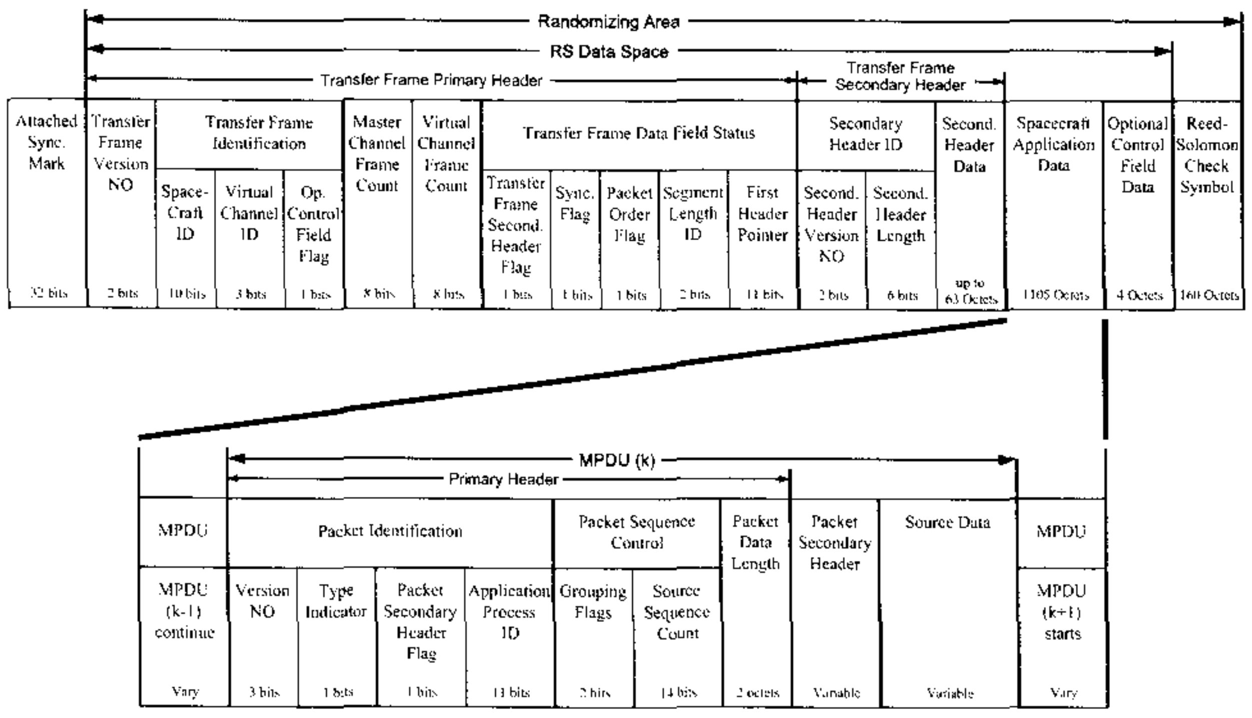

Figure 5. TM Space Data Link Protocol

The advantage of using TM space data link protocol is it has two channel counters for master and virtual channel. Normally this makes easier to find error location (which unit) when detect an error on the ground station. But this cannot help K-3 system because the IDHU performs master channel coding and virtual channel coding same time at the IDHU output interface board.

The disadvantage of TM space data link protocol is that there are only 7 user defined virtual channels. In K-3 payload 10 kinds of data are exist. 4 PAN data, 4 colored MS data, 1 Additional image data and Auxiliary data from the IBMU. So it is impossible to distinguish all kinds of payload data within given number of VCID bits. One suggestion of the virtual channel assignment is assigning three different kinds of virtual channels in the IDHU. One is for the image data including PAN, MS and additional image, the other is for auxiliary data and the last one is for fill data for Fill CADU generation while there is no data to transmit. By doing this we can prevent to generation fill source packet data between changing virtual channels. In transfer frame level, every time to change transfer frame data to another virtual channel data, unused transfer frame area of previous virtual channel data should be filled by the virtual fill source packet. If the unoccupied area is less than 7 bytes the situation goes worst because the minimum size of the virtual fill source packet data is 7 bytes. So less changing virtual channels has more efficient transfer rate.

The advantage of the AOS space data link protocol is that there are 63 virtual channel spaces enough to represent all image bands and data of K-3 payload. And also it has a special field, replay flag, to represent that this downlink data is replayed data or realtimed data. One disadvantage if the AOS space data link protocol is it needs two more bytes for the header than the TM space data link protocol. This is a minor problem.

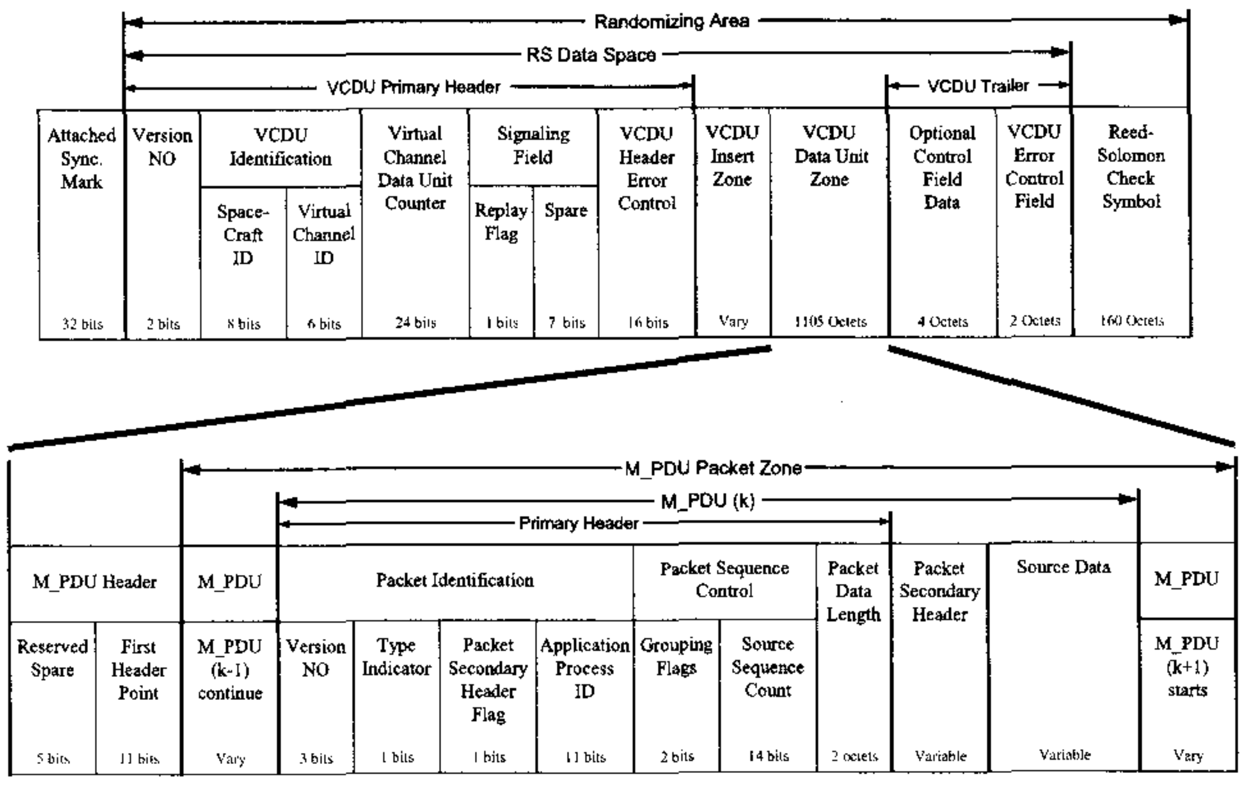

Figure 6. AOS Space Data Link Protocol

2.4 Additional Information

Additional information represents the characteristics of the packets such as information about compression and encryption and the information about whether this download data is a replay data or realtime mission data. Without this information on the X-band data packet the ground station can decode the data packet because the ground station has all historical information of the mission and the transmission. In case of using another ground station for the Image Reception & Processing Element (IRPE), the ground station which controlled the satellite and uploaded the command shall hand over mission and transmission information to the remote IRPE. So sometimes the ground station wants to have all information to handling image data inside downloaded data packet.

To insert additional information in a transfer frame one of possible way is using Operational Control Field (OCF) in a transfer frame. The OCF is existed on both TM space data link protocol and AOS space data link protocol. The advantage of using the OCF field is that we don't need to modify on transfer frame primary header. But there is a side effect on this, the ground station have to look the OCF field which is located later than image data to process the image data. In case of the ground station has a sufficient memory buffer for image processing and has enough time to process two steps, this can not be a problem. Below Table 1 shows an example of using OCF. The Compression Index can be split into PAN compression parameters and MS compression parameters.

This OCF is located at the end of each transfer frame. Theoretically the information about compression should be located in source packet OCF because the compression function is performed at source packet level. By setting same compression parameter to all PAN image data and setting same compression parameter to all MS image data, it's easy to put compression index information on the OCF field of the transfer frame. The compression parameters will not be changed during the mission. Data encryption function is operated within virtual channel access sublayer of the space link subnet as the CCSDS recommends for the most security and manageability.

Table 1. An Example of OCF Definition

Field	Contents
B3	0x00 – Realtiem Transfer 0xFF – Replay Transfer
B2	N/A
B1	Compression Index
B0	Encryption Index

The second way to represent additional information is using virtual channel transfer frame secondary header. The advantage of this is additional frame information is located before the image data while no modification on transfer frame primary header is required. But the ground station has to decode the transfer frame header twice. An example of using virtual channel transfer frame secondary header is below table.

Table 2. An Example of Transfer Frame Secondary Header

Field	Contents
Secondary Header Version	0b00
Secondary Header Length	0b000010
Secondary Header Data B2	0x00 – Realtiem Transfer 0xFF – Replay Transfer
Secondary Header Data B1	Compression Index
Secondary Header Data B0	Encryption Index

The third way to add additional information into transfer frame is to modify signalling field on transfer frame version-2 primary header. As you can see on Figure 6. only 1 bits are used for replay flag among the assigned 8 bits. The rest 7 bits are spare on the current transfer frame version-2. It can be modified to represent additional information. Actually it's slightly out of CCSDS recommendation but it neither needs additional field nor increases the transfer frame size.

Table 3. Modification of Signalling Field

Field	Contents
Replay Flag : b(7)	0b0 – Real-time 0b1 – Playback
Spare : b(6)	0b0 – No Compressed 0b1 – Compressed
Spare : b(5:0)	Encryption Index

The actual compression index of the transfer frame data is not required because normally the compression parameters required for decompress the image data is location at compress header data. So one bit s enough to mark this transfer frame data is compressed data or un-compressed data. The rest spare bits are filled with encryption parameters used for the generation of the transfer frame data.

It's also possible to define transfer frame header totally different from the CCSDS recommendation to make it the most suitable for the K-3 program. That will lose all advantages while using CCSDS recommendation.

Considering the efforts to be made and its efficiency, it seems the best to modify signalling field of transfer frame version-2.

3. CONCLUSION

On this paper considerable points are listed and checked to determine K-3 X-band transfer frame format. To transmission of ancillary data, using CEU header space is reviewed. About source packeting, it's suggested not to use source packeting due to the IDHU has to perform all source packeting and transfer frame packeting in the output interface board at a same time. AOS space data link protocol with slightly modification on signalling field is suggested for better performance in transmission of additional information.

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