IPCM TELEMETRY SYSTEM: EXPERIMENTAL RESULTS

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ABSTRACT

The aeronautical industries have been suffering financial cutbacks and the market has to face new challenges associated with new companies. Telemetry community has been facing the increase of the electromagnetic spectrum usage for a variety of applications (e.g. 4G), after all telemetry is everywhere. In view of these issues and focused on the inherent requirements of the Flight Test application, the IPEV R&D group proposes the iPCM Telemetry architecture as solution for the existing reliability and bandwidth issues associated with the telemetry link. In this article, as a proof-of-concept of the iPCM architecture, it has been performed an experimental assembly. The results demonstrate the iPCM's ability to regenerate corrupted data providing the required data integrity and reliability, besides the capability to dynamically select the FTI transmitted parameter list to optimize the bandwidth link.

KEY WORDS

Flight Test, Telemetry, Bandwidth, Reliability, iPCM

1 INTRODUCTION

Every aeronautical design and avionics systems regard to be tested and undergo rigorous certification processes according to national and international standards in order to ensure reliability and safety during the operation. One of the areas related to this activity is flight test, where it assesses in real conditions, what is predicted by the standards and engineering analysis. Although prediction and simulation techniques have advanced considerably in recent decades, flight tests are still essential for validation and certification of aeronautical projects and embedded systems. However, this activity involves risks related to flight safety and high costs with infrastructure, flight hours and qualified personnel.

Regarding safety and efficiency the Real Time Telemetry Link (RTL) is one of the fundamental tools for successful completion of a flight test campaign. However, over the years the deficiencies of the adopted protocol for wireless data transmission in flight test has become well known. Nowadays the international community of flight test concentrates efforts in order to achieve the objectives to perform the flight test with how much safety as possible and at the same step reduce costs. For this, innovative techniques have been developed for real time data reduction in order to make the test campaigns most efficient [1]. In addition, great efforts have been put to minimize the repetition of flights whether by losses or by low quality of the data acquired from the telemetry link. However, for the success of these objectives it is essential a Telemetry Link (TL) to obtain the data from the test platform with reliability and quality within acceptable standards. In the particular case of low risk test flights carried on medium or large sized aircrafts, these inherent TL issues can be overcome. At such condition it is possible to include a full flight test crew airborne to perform the flight test coordination, data validation and data reduction analysis. In this case the TL is downgraded to a secondary role. On the other hand, when the test platform is a Remotely Piloted Aircraft (ARP), fighters or guided weapons, the TL plays a vital role to the test campaign safety and efficiency. In this case, the operational scenario for the development and certification test campaigns includes several test points carried under high dynamics flight regimen, where the TL signal to noise ratio (SNR) is degraded and consequently the signal losses rate is higher.

After decades in use, the telemetry protocol based on the IRIG-106/13 Standard Chapter 4 [2] has endured with almost with no changes, due to its high efficiency and low complexity architecture. However, the reliability of this protocol has been under check. Although its high efficiency, it has no mechanisms for data recovery when degradation of RTL quality or signal abrupt losses occur. Engineers have been trying to find new protocols to solve this issue, but it still with no final solution. The most discussed architecture is the Integrated Network-Enhanced Telemetry (iNET) [3], based on the Ethernet protocols, aiming the implementation of telemetry networks with wideband wireless capability, high reliability and covering vast areas, similarly to a large computers network. However, the use of Ethernet protocols such as Transport Control Protocol (TCP) [4] or User Datagram Protocol (UDP) [5] do not achieve the transmission requirements of the flight test environment, as addressed in references [6] and [7].

Associated with the high usage demand of the available bandwidth, due to the telemetry employment in several areas of industry, the telemetry link also brings great challenges, keeping open the discussion to the study of new technologies that will meet the actual flight test community requirements that are based on the real needs to improve the reliability and the data analysis efficiency [8]. Faced with this real need the Instituto de Pesquisas e Ensaios em Voo - IPEV (Flight Test and Research Institute) and the international flight test community, emerges the idea of creating an efficient protocol based on legacy PCM protocol specified by IRIG-106/13 standard [2] employing algorithms to evaluate quality of data and losses identification associated with two telemetry channel in order to allow recovery the lost data by telemetry link during flight. This solution should encompass the improvement of TL reliability and integrity leading to a more effective usage of the telemetry, which is everywhere.

2 INTEGRATED PULSE CODE MODULATION (iPCM)

The Integrated Pulse Code Modulation (iPCM) [9] was designed to provide new features for the flight test community. The iPCM encompasses the integration of new capacities for the legacy transmission protocol to address data transmission reliability issues and bandwidth efficiency usage. Consequently the iPCM is a way to solve the recurring issues related to the reliability of the TL. This technology employs PCM IRIG-106/13 Standard Chapter 4 [2] and algorithms that verify the received data quality and integrity to identify corrupted and lost information. Employing two telemetry channels (i.e. RT and QRT channels) iPCM provides the capacity of retrieve the lost data from airborne FTI. Consequently it is possible to recover the full flight data set during the flight test and use them in the second channel, which will be treated as a Quasi Real Time Channel (QRT). During the execution of the flight test, such data could be used for test point validation and data reduction analysis.

For instance, if the test bed leaves the system range or deviate from the antenna beam, when it returns and the telemetry link was reestablished, all the lost data will be sent back to the ground station. This capability allows maneuvers to be performed outside the antenna envelope and keep the ground crew updated during the flight test. The basic architecture of the iPCM system is composed of (Figure 1):

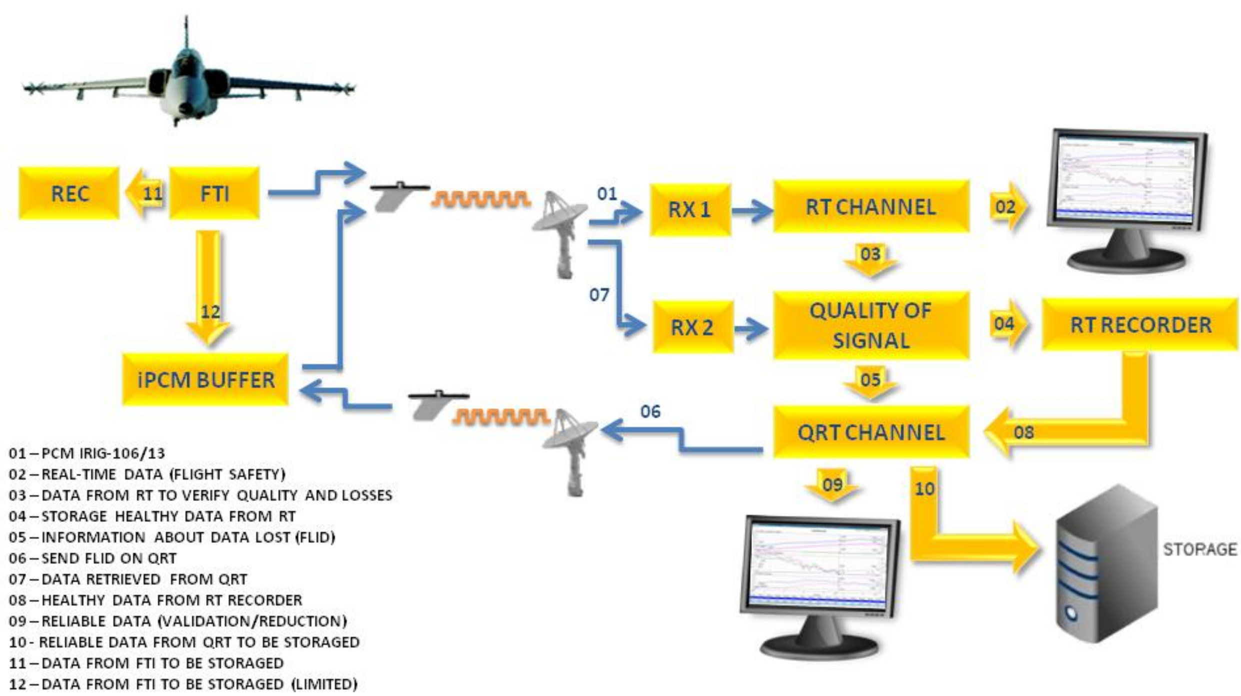

Figure 1 - iPCM Architecture

1. Airborne System:

   a. Flight Test Instrumentation (FTI) with the frame counter programmed, termed Frame Lost Identification (FLID);
   b. Data Recorder (REC); and

c. iPCM Buffer: This system storages flight data and perform read while write feature. Its main function is to identify the requested data by the FLID and sends it back to the ground. iPCM Buffer also has a capability of receive control commands to select which set of data will be transmitted in order to improve bandwidth usage.

2. Ground System:

a. RT Channel: Legacy PCM IRIG-106/13 Standard Chapter 4 [2] telemetry system to receive data in real time;
b. The function QUALITY of SIGNAL (QoS) is detect failures in the received data and identify the lost frames sending this information to the QRT Channel and store the healthy data received from RT Channel in the RT RECORDER;
c. The function QRT CHANNEL, which is responsible to receive the FLID and sends it to the iPCM BUFFER for the information retrieval. The QRT Channel system recovers the full data set appending received data from second channel with the stored health data in the RT RECORDER.

3 EXPERIMENTAL RESULTS

This work was carried out in order to make a proof of concept of the iPCM system which was only tested in computer simulations [9]. It was not possible to have a final prototype at this point, but it was tested the software and the hardware involved in the process of reception, transmission and decomutation available in IPEV (Flight Test and Research Institute) telemetry station (Figure 2).

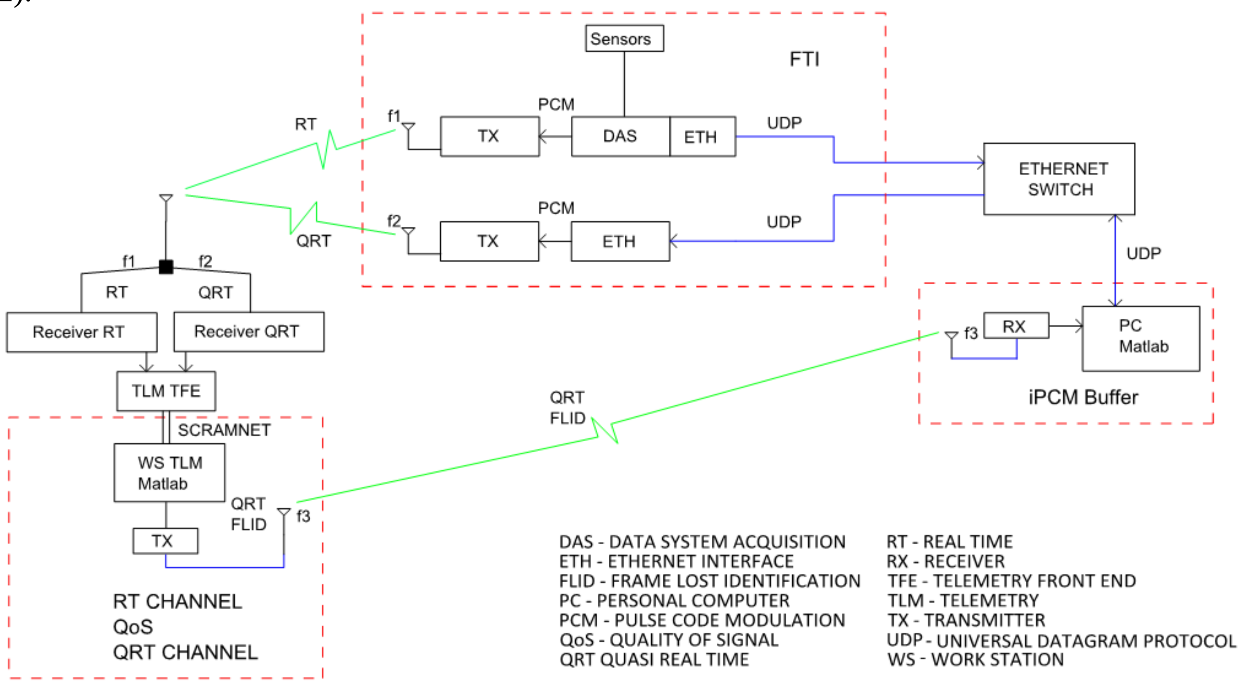

Figure 2 - iPCM Antenna Assembly

To achieve this purpose, a desired final state was defined for this phase, as well as sub-phases for the implement of the experiment. The work was started with the purpose to carry out the assembly of the experiment, as shown in Figure 2, where it would be possible to test the system in a controlled environment, both on the ground and in flight, with suitable constraints for control and analysis of the variables involved in the process. Regarding on the aforementioned figure, the current work status is in the subphase represented in Figure 3.

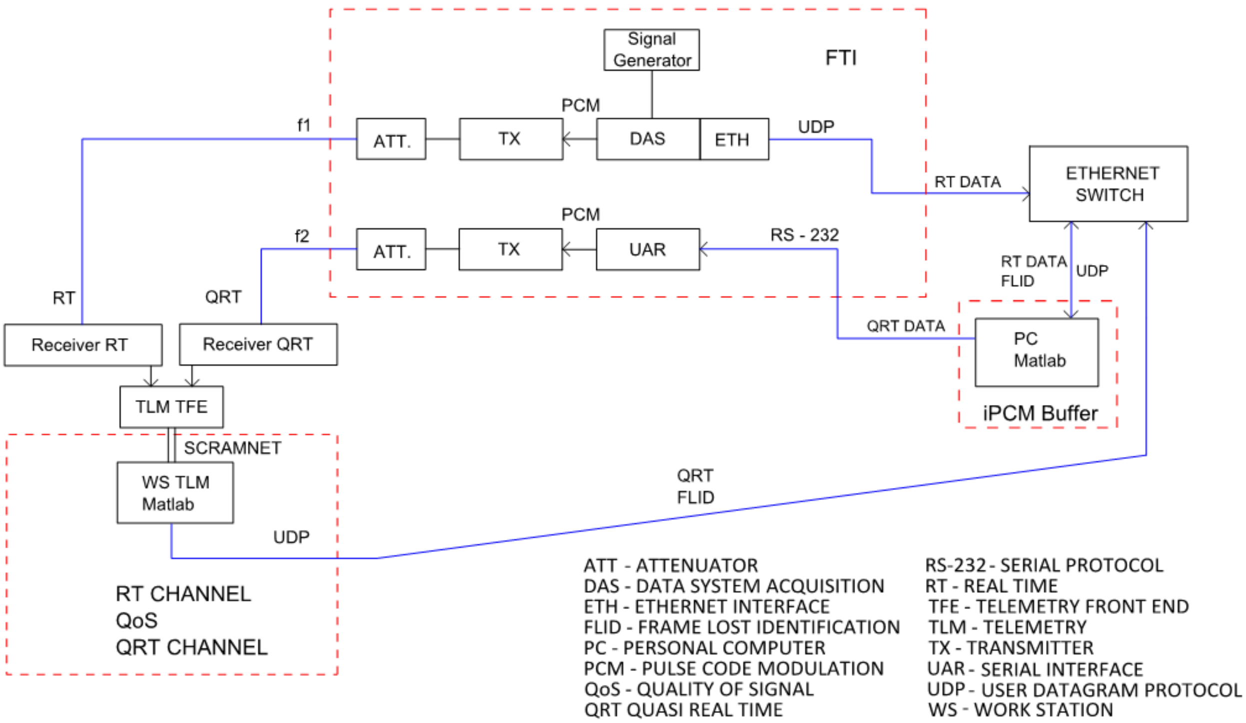

Figure 3 - iPCM Cable Assembly

This subphase is a previous step to the final state mentioned before, and includes all software for logical processes implementation and all real telemetry station hardware. The difference between this assembly from the proposed one in Figure 2, lies on the fact that it was employed a wired communication between system components. This methodology was used to allow a better control of the variables and the environment to provide the development and testing of the functionalities of both hardware and software of the system as a whole. The results obtained until this sub-phase were treated in this work.

The experiment assembly could be better performed dismembering the iPCM system in Airborne System and Ground System. The Airborne System encompasses the FTI and the iPCM Buffer while the Ground System includes all telemetry station systems added to RT Channel, QoS and QRT Channel. FTI is comprised by a KAM-500 data acquisition system (DAS), acquisition cards, telemetry transmitters QSX TIMTER, signal generator to emulate flight data and Ethernet and Serial interfaces to exchange information between the systems.

The primary role of FTI is data acquisition, data storage and sending data to the telemetry station via PCM protocol by QSX transmitter and to iPCM Buffer via UDP protocol by telemetry network. In addition, it receives the data retrieved sent by IPCM Buffer via RS-232 and sent back to the telemetry station via PCM protocol by a second transmitter.

The iPCM Buffer was designed in Matlab® and Simulink® [10] environment aimed to receive via UDP protocol by telemetry network the data packets generated by the DAS and stores them. Additionally, it receives the frame identifier FLID, sent by QRT Channel. After receiving the FLID, the program identifies the data to be retrieved and send it back via RS-232 to the UAR interface present in FTI system, which converts the serial data to PCM IRIG-106/13 protocol and transmits it to telemetry station by a second telemetry transmitter QSX TIMTER. The iPCM Buffer also can receive commands to select the appropriate format previously programmed in the DAS. It is possible using an interface that receives the command from iPCM Buffer and set 0 V or 5 V to select lines values. There are 15 available formats for user application in KAM-500 [11].

The telemetry system employed encompasses all real hardware components and software of the telemetry station. To receive the data, two telemetry receivers operating in L and S-band were used associated to all real system of decomutation and processing as Telemetry Front-End (TFE) and Work Stations (WS), all them interconnected by a high performance network of SCRAMNet® type. In order to change the format during the flight, it is necessary that the database of telemetry station has been previously programmed for each FTI format. In addition, when the QRT Channel sends the command to the iPCM Buffer to change the FTI format, at the same time the command “switch” must be performed in the telemetry workstation in order to load the new compatible format in the telemetry system to allow the new set of data might be decomutated e processed.

Thus, the data from the two PCM streams are provided on a WS connected to both networks available in the telemetry station, SCRAMNet® and telemetry network. For dealing with these data, programs were implemented in Matlab® and Simulink® [10] environment: RT Channel, responsible for receiving data from the telemetry real time channel and make them available to the ground crew for decision-making;

QoS receives the real time and retrieved data and analyzes them detecting failure and identifies which data packets should be retransmitted. To fulfill this function, QoS make use of parameters from Receivers and Telemetry Front End system, besides checking control parameters inserted in specific positions along the frame and determines the FLID and sends it to the QRT Channel. Furthermore, the QoS excludes corrupted data and stores healthy data obtained from RT Channel;

QRT Channel is responsible for sending FLID information to iPCM Buffer, additionally it receives the retrieved data returned by iPCM Buffer and regenerates the complete information by adding the retrieved data with the healthy data received from the RT Channel and recorded by QoS, in an orderly manner.

For the test setup were used two identical PCM frames to RT Channel and QRT Channel with the following characteristics: Words per minor frame: 64; Minor per Major frame: 1; Bits per word: 16; Fill pattern: AAAAh; Bit rate: 32,768 bit/sec; Bits per minor: 1024; Sync. pattern: FE6B2840h; PCM code: NRZ-L; Acquisition cycle: 32 Hz. In this case it was created a simple frame to make the implementation and data analysis easier. Fixed parameters and parameters generated from the signal generators were inserted in frame structure in order to reproduce the data acquisition in flight. The serial interface RS-232 was set with the baud rate of 230,400 baud; 8 data bits; 1 stop bit; no parity; no hardware control. The original intention was to use UDP instead of RS-232, but this second option did not affect the results of the experiment and it was available for immediate use in the telemetry facilities.

Imperfections were included in the RT Channel via software by a specific function adding white Gaussian noise and/or complete losses on the received data from the telemetry system. Another important point to consider is the fact that in the real system the RT and QRT channels will be compatible in performance and will be susceptible to the same wireless environmental issues under the operating conditions, therefore when there is a failure in the RT channel the QRT will remain inoperative until the channel status will reach the minimum operational conditions. This critical condition can even occur during data retrieval and the system will be robust enough to keep on transmitting all requested data after finished this condition. However, in the present experiment, the QRT was not susceptible to loss and it was independent of the RT conditions and it could continue their retransmission even RT was under losses or noise.
Some tests were carried out separately for testing the functions of an exchange format in order to optimize the bandwidth usage. It was employed a microcontroller coupled to IPCM Buffer to generate the logic levels required for selecting formats in the DAS from the corresponding pins of Bus Controller Unit [11].

To analyze the experimental results it was used an analog parameter derived from the signal generator. This parameter has been generated from a sinusoidal signal with amplitude of 5 Vpp and frequency of 0,050 Hz, acquired by DAS. According to Figure 4, it is possible to verify the signal received from the RT channel with simulated noise and losses and additionally, some spikes could be identified, which was originated by the own real telemetry system. Figure 4 also brings the data returned by QRT Channel.

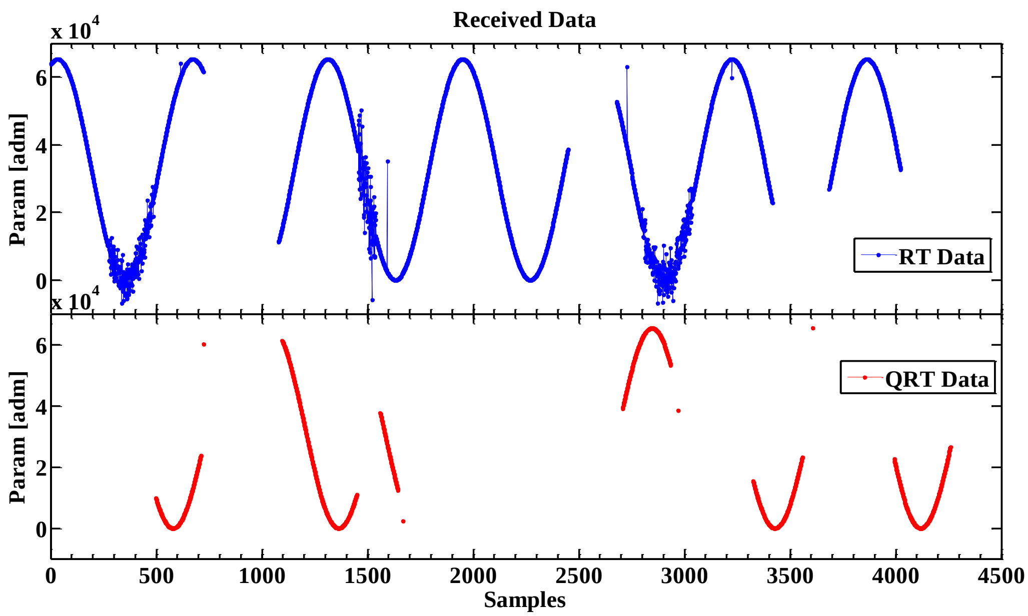

Figure 4 – RT Channel Data versus QRT Channel Data

From the analysis of these data it was possible to conclude that the system was able to recover corrupted data due to simulated noise and losses and also retrieving the corrupted data by spikes occurred in the real telemetry system. However, there was an increase delay in the data received from QRT Channel over the time. This can be verified by analyzing the first set of data received from QRT Channel compared to the last set, which occurs only after about 300 samples after the ending the loss at RT Channel. This delay is predominantly attributed to the telemetry network employed in the experiment, which had a great number of equipment connected by the same network switch. The time processing magnitude was despised for being about 20 times smaller than the acquisition period configured in the DAS.

In order to complete the data recovery sourced in the RT Channel these data were processed by QoS and stored only healthy data, which are presented in Figure 5. This figure also presents the recovered data and processed by QRT Channel which is now delay free.

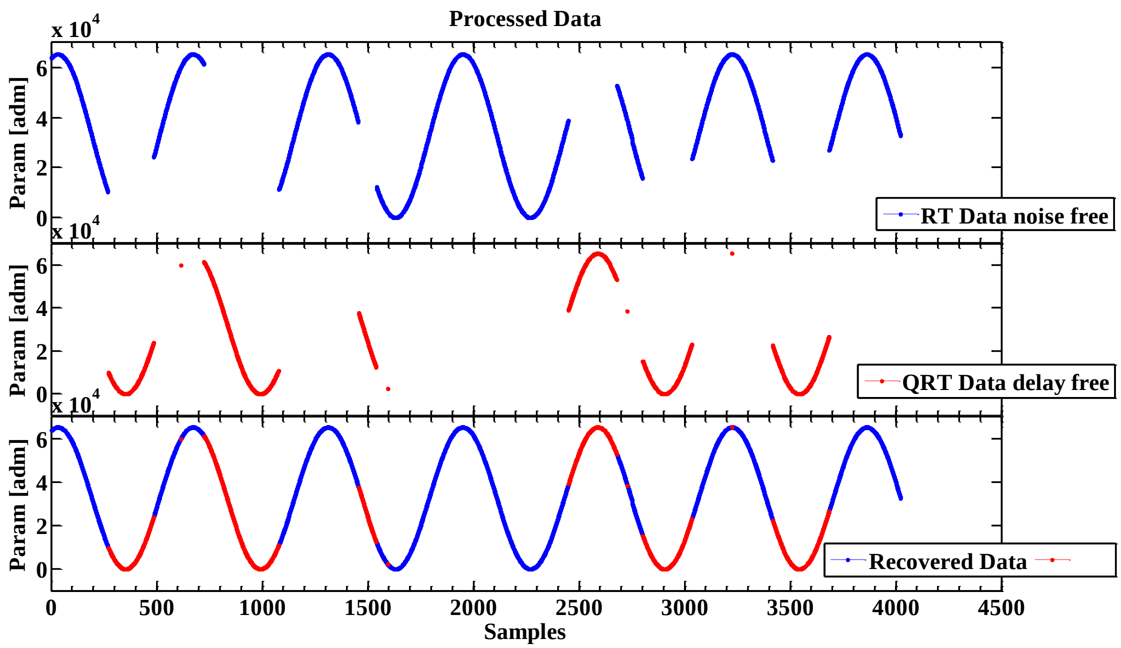

Figure 5 – Processed Data and Recovered Data

Using the healthy data received from the RT Channel and stored by the QoS added to the data retrieved with delay free, the QRT Channel merged them in an orderly manner, regenerating the full information free of imperfections in the telemetry station, enabling the use of these data by ground crew for data reduction and test point validation in a real flight test campaign.

In legacy telemetry systems based on PCM IRIG-106, when the data is corrupted it is necessary to await the test platform return from flight for the complete data recovery from the FTI data recorder. However, the iPCM proposal consist of provide reliability to the protocol making available all data during the flight unless a delay. This feature was proved in the performed experiment, considering the test conditions, and the result can be verified in Figure 6.

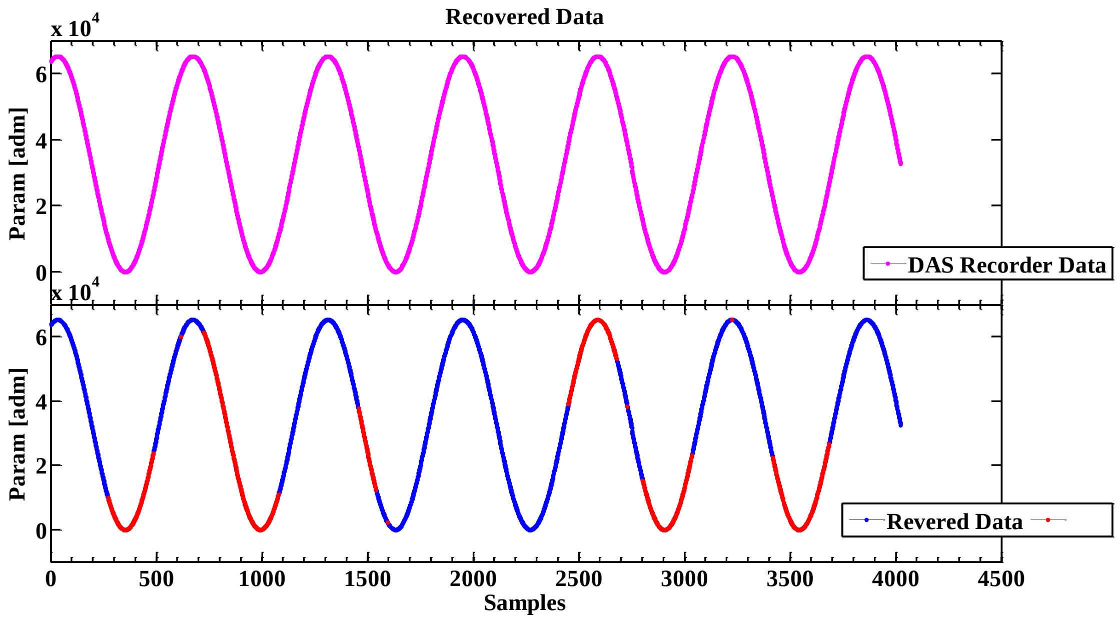

Figure 6 – FTI Data Recorded versus iPCM Data Recovered

In Figure 6, the strip charts refer to the parameter analyzed, obtained from the data recorded by FTI, in comparison with the telemetry data regenerated by iPCM system. It may be verified that the curves are identical, and the data were satisfactorily recovered, given the test conditions which the system was undergone. Thereby, the data obtained from the experiment performed on the IPEV telemetry station facilities can be considered as the proof of concept of the iPCM system implementation viability as a way to add reliability and more efficiency to the telemetry channel.

4 CONCLUSIONS

In this paper it was presented the iPCM protocol architecture and some experimental results aimed to improve the reliability and bandwidth usage. An experimental setup was assembled using the real telemetry hardware and software providing significant results in a lossy environment. The systems were wired connected to allow a better control of the variables and environment to provide the suitable development and testing conditions. The results obtained from the experiment shows that data were satisfactorily recovered after losses occurred and the data retrieved can be compared with the data recorded by FTI embedded on aircraft. Based on the results, the iPCM system implementation viability was demonstrated as proof of concept of the proposed architecture.

The next step is to apply the iPCM in the wireless environment, test it in limit situation and install the airborne system in an aircraft for assessment in a real flight test conditions.

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