ADVANCED DISTRIBUTED WIDEBAND DATA ACQUISITION SYSTEM

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ABSTRACT

Wideband data acquisition units have been used as part of an instrumentation system for several decades. Historically, these units operated asynchronously from each other, and from the rest of the instrumentation system when installed on the same test vehicle. When many wideband units are required to slave their formats or sampling rate to the test vehicle's event of interest such as external computer event clock, radar, or laser pulse train; few solutions were available. Additionally, a single test vehicle may use ten to thirty wideband units operating at up to 20 Mbps each. Such systems present a challenge to the instrumentation engineers to synchronize, transmit safety of flight information, and record.

This paper will examine a distributed wideband data acquisition system in which each acquisition unit operates under its own data rate and format, yet remains fully synchronized to an external fixed or variable simultaneous sampling rate to provide total system coherency. The system aggregate rate can be as low as a few Mbps to as high as 1 Gbps. Data acquired from the acquisition units is further multiplexed per IRIG-106 chapter 10 using distributed data multiplexers for recording.

KEY WORDS

Wideband, Simultaneous Sample, Data Acquisition, Recorder, IRIG-106 Chapter 10

INTRODUCTION

Wideband data acquisition units are generally used when acoustic, structural, and flight dynamics data is to be monitored and acquired. Sensor data sampling rate varies from a few hundred to tens of thousands of samples per second. Due to the high sampling rate per channel, a unit with tens to hundreds of channels can quickly reach data rates of up to 20 Mbps. Most wideband units utilize local simultaneous sampling for data coherency across some or all of the data acquired by the unit. When multiple wideband units are used on a test platform, they would generally acquire data with different channel capacities and therefore would operate at different bit rates. When channel capacity and data rates were identical across multiple wideband units, potential synchronization are possible across a few units but not across a test platform with tens of units on a single test platform. As a result, wideband units operated autonomously from each other, and no data coherency was available across multiple units.

This paper describes a systematic approach taken which provides a total system solution of configuring, acquiring, synchronizing, and recording per IRIG 106 Chapter 10 multiple wideband acquisition units such that data coherency across the entire test platform is maintained. In addition, this paper describes additional capabilities that allow the entire set of wideband system to lock its sampling rate to an external aircraft sampling source.

SYSTEM APPROACH

The development of a wideband solution that allows the user with complete flexibility and virtually no constrains in allocating wideband sensors across a test platform is not a simple task. Such a flexible system must be developed from the top down, namely from the overall system point of view first before the detail of the various subsystem designs commences. A good multi-level approach takes into account various user functional scenarios. These user scenarios are compared against real customer needs and/or user wishes. Once multiple system cases are studied, a list of requirements is derived from which the system and all subsystem units are developed. The approach must take into account the potential of future technology insertion by developing a modular system. The system approach must address the following key requirements:

- The system shall be programmable from a single point
- Each wideband unit shall be capable of operating at its own rate, independent of the operating rates of other wideband units and without restriction on the resolution
- Narrowband and wideband units shall coexist within a single system
- The architecture shall allow subset data selection from any or all units for transmission of flight safety information
- All wideband data shall be capable of simultaneous sampling through a system wide synchronization strategy to allow data coherency across the system.
- Each wideband unit shall be capable of operating up to 20 Mbps - data output from each unit shall be PCM with a future capability of 10/100BaseT data.
- Any wideband unit shall be capable of operating as a standalone unit
- A wideband unit shall optionally be configurable with a CAIS bus interface for system wide programming, setup, audit, synchronization, and data sampling of flight safety information.
- A wideband unit shall accept and phase lock its' major frame to an external or inbound (CAIS bus based) synchronization signal.
- Two or more wideband units that do not use the CAIS bus, shall be capable of synchronizing their frames (not bit rate) by way of an external synchronization signal.
- The wideband external synchronization signal may be variable - the variability can be due to the Doppler rate change of a moving test platform or target.
- The overall aggregate rate of the system with multiple wideband units shall be up to 1 Gbps - the aggregate data shall be multiplexed and recorded per IRIG 106 chapter 10.
- The multiplexer / recorder shall be capable of acquiring PCM as well as 10/100 BaseT Ethernet data.

It can be seen from the list of key requirements that this is a difficult problem to solve. If a solution could be found, it would provide the user with a very flexible system with unparallel data coherency across hundreds and possible thousands of wideband channels on a single test platform. One solution for this problem is found by dividing the system into three functions, namely, the use of the CAIS bus as the common wiring across the system, the wideband architecture, and the distributed multiplexer / recorder system.

THE CAIS BUS INTERFACE

The CAIS (Common Airborne Instrumentation System) bus has been around since the early 90s. It has been used in most major programs in the US as well as around the world. The bus utilizes four wires of which two wires are used for command bus and two wires are used for the reply bus. The bus is a highly deterministic one using Biphase-S coding at 10 Mhz with data bandwidth at up to 5 Mbps. Although the bandwidth of an individual bus is low, a system controller employing multiple CAIS buses can be used to easily achieve 20 Mbps - such a controller is currently being used all over the world. In the case of the distributed wideband data acquisition system aggregating data at several hundreds of megabits per second, a 5 Mbps CAIS controller unit can be used. The CAIS bus is utilized in this application to provide a user with the following capabilities:

- Provides single point programming to all data acquisition units, wideband units, and a distributed multiplexer / recorder system.
- Provides overall system audit of system elements down to the signal conditioning card / module level.
- Provides single point monitoring of system health status from all subsystem units.
- Allows data selection of any parameter from any or all subsystem units for transmission of flight safety information.
- Provides inbound synchronization signals to all wideband units in the system - wideband units can be configured to lock their major frames to the CAIS bus using:
    - Minor Frame signal, or
    - Major Frame signal, or
    - Simultaneous sample signal, or
    - Any combination of the above three signals.

WIDEBAND UNIT ARCHITECTURE

The wideband unit discussed (MWDAU-20XX) in this paper has many features common with wideband units already deployed in many programs. These features include the acquisition of acoustic, structural and flight dynamics data. Generally, this data is sampled at a high sampling rate. A single wideband unit can achieve data rates of up to 20 Mbps. When multiple wideband units are used as part of a single data acquisition system, determination of real timing and cross correlation of acquired data represents a serious challenge to the flight test and data analysis engineers. This challenge is more significant if data samples from multiple wideband units must be coherent to an external (aircraft) event rate. The general solution is for each wideband unit to provide a PLL capability such that all wideband units operate at a common major frame rate equal to the external event rate. When the aircraft external event rate is variable due to the

Doppler effect from either the moving test platform or a moving target, this represents an even more challenging task to the design of the wideband system and the signal conditioners within each unit. This is exactly what has been achieved by the development of the wideband data acquisition system described in this paper.

As a standalone unit, the wideband units can be configured to operate at up to 20 Mbps in steps of a fraction of 1 Hz. Multiple standalone wideband units can be independently configurable (with or without a CAIS bus) to operate with different numbers of channels, and different (not related) bit rates, and yet be synchronized to an external common aircraft sampling event rate. The sampling event represents a common major frame across multiple standalone wideband units.

For example: Assume external sample event is 3500 Hz:

> Unit A operates with 50 Samples per minor frame, 4 minor frames per major frame, and 16 bit resolution. This results in 50 x 4 x 16 = 3200 bits per major frame.
>
> Unit B operates with 137 samples per minor frame, 2 minor frames per major frame, and 16 bit resolution. This results in 137 x 2 x 16 = 4384 bits per major frame.
>
> Unit A bit rate will be 3200 x 3500 = 11.2 Mbps
>
> Unit B bit rate will be 4384 x 3500 = 15.344 Mbps

In the above example, unit A and unit B will synchronize to the external sample event of 3500 Hz. Both units will lock to the external sample event and operate at 3500 Major frames per second. Unit A will operate at 11.2 Mbps based on its bits per major frame, and unit B will operate at 15.344 Mbps. If both units assert their simultaneous sampling at the major frame rate, both units' samples will be coherent to each other. If the External sample event is variable, it is expected that each wideband unit locked to the external sample will vary its bit rate to maintain major frame lock.

This example can be applied to many wideband units operating in the standalone mode, or interconnected through the CAIS bus. The same calculations applied to the external sample event can also be applied to the CAIS minor, major, or simultaneous sample signal.

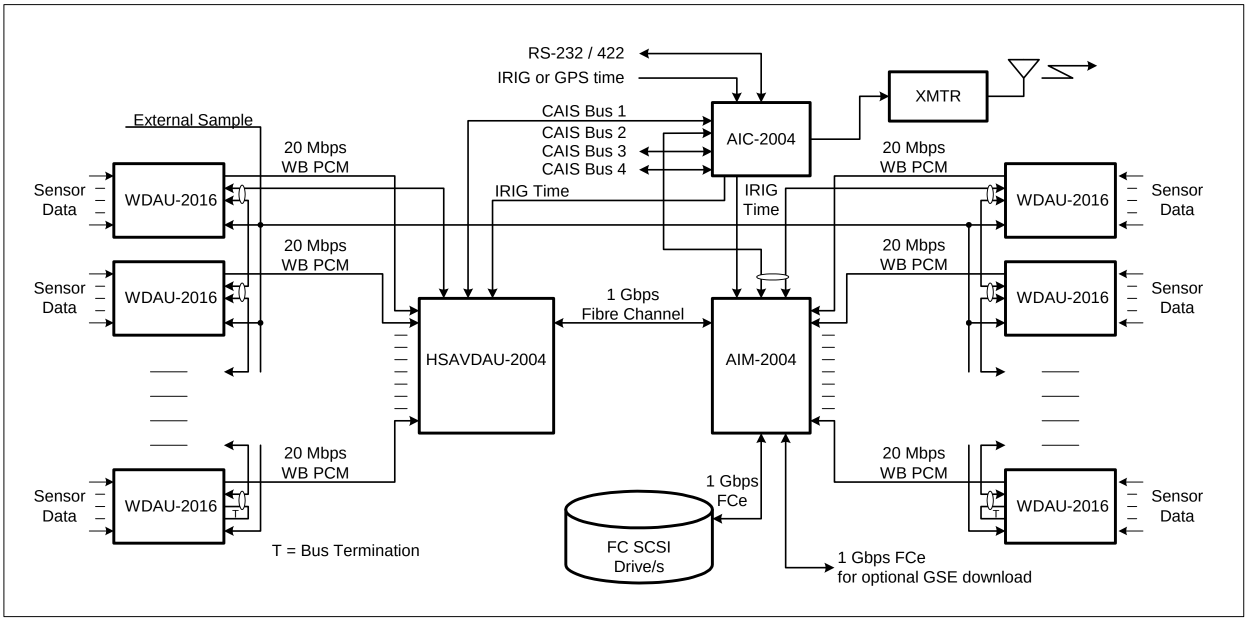
DISTRIBUTED MULTIPLEXER / RECORDER SYSTEM

The aggregate data acquired from the wideband units can be from few tens of megabits per second to hundreds of megabits per second. This data must be acquired from the wideband units for recording. It is preferable the acquisition of this data be as close as possible to the data source to minimize wiring. The data from the wideband units is in the form of PCM data and clock, however, a 100BaseT Ethernet is a future capability for the wideband unit, while it already exists in the multiplexer / recorder system. The multiplexer/ recorder system utilizes four 20 Mbps channels per card. A system with TTC's HSAVDAU-2004 and AIM-2004 can accommodate a total of 6 cards, each with four PCM or four 100 BaseT channels per card achieving a total of 24 channels. The aggregate rate of such a system can be 480 Mbps. Additional units can be added to achieve even higher rates. The recorder interface is a 1 Gbps electrical fibre channel. The recording media can be any off-the-shelf fibre channel media such as a JBOD (Just Bunch Of Disks) unit, a RAID unit, TTC's MSR-2002 or MSR-1001, or any other media.

The recording format is per IRIG-106 chapter 10. This format allows the user to record data other than just PCM or Ethernet. The multiplexer / Recorder system allows the user to record MPEG 2 Video, Audio, MIL-STD-1553 bus, W-Mux Bus, Fire Wire 1394B bus, Fibre Channel data, Fibre Channel video and others.

Figure 1 shows the overall distributed wideband system diagram.

Figure 1. Overall Distributed Wideband System Diagram.



CONCLUSIONS

Acquisition of wideband data using a distributed system and maintaining data coherency across a large system is possible. The paper described various strategies available to synchronize a distributed wideband system. The advent of IRIG 106 chapter 10 makes it possible to collect a vast amount of data from many wideband units, and record that data on single or multiple drives. This system is currently deployed and has been in operation for over a year.

REFERENCES

1. Berdugo, Albert A., “Design of a Gigabit Data Acquisition and Multiplexer System”, Proceedings of the International Telemetering Conference (ITC 2003), Las Vegas, NV USA, October 21-23, 2003.
2. Berdugo, Albert A., “Design of a Gigabit Data Acquisition and Multiplexer System”, Proceedings of the European Telemetry Conference (etc 2004), Garmisch-Partenkirchen / Germany, May 24-27, 2004