INTEGRATING A GROUND WEATHER DATA ACQUISITION SYSTEM AND AN AIRBORNE DATA ACQUISITION SYSTEM

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ABSTRACT

During engine and airfield performance testing it is often necessary to acquire weather data at the airfield where the test is being conducted. The airborne data acquisition system (DAS) acquires data associated with flight parameters. A separate system records airport weather conditions. Many times the separate system is an Automated Terminal Information Service (ATIS) or the ground crew relaying wind speed, wind direction and temperature from a weather station. To improve this system, the weather station is designed to acquire and store the data in memory. Utilizing a second DAS that is remote to the airborne DAS poses several problems. First, it is undesirable to have many different data acquisition systems from which to process data. The problem then develops into one of integrating the ground weather DAS with the existing airborne DAS. Other problems of system integrity, compatibility and FCC licensing exist. Complete system integration while maintaining integrity and compatibility is overcome by controlling signal format, flow and timing and is discussed in detail. Further discussion of the issue of transmission is overcome by a technique called spread-spectrum and is used in accordance with FCC rules and regulations.

KEYWORDS

weather station, airborne data acquisition system, RS-232 to ARINC-429, spread spectrum, asynchronous, airfield performance testing, engine performance testing

NOMENCLATURE

ARINC-429	Aeronautical Radio, Inc. standard data bus format -429 for aircraft
ASCII	American Standard Code for Information Interchange
ATIS	Automated Terminal Information Service
A-D	Analog to Digital
CFR	Code of Federal Regulations

DAS	Data Acquisition System
FCC	Federal Communication Commission
PCM	Pulse Code Modulation
RS-232	Electronic Industry Association standard of signal level/format for serial communication

INTRODUCTION

The mobile and remote weather station is designed to meet certain specifications which best facilitate the requirements for data acquisition. For example, the weather station must acquire air temperature, wind speed, and wind direction at a 1Hz rate, as well as, electronically record and time stamp the data. It is also desirable to merge the weather data with the existing aircraft DAS for ease of test documentation and data processing. The integration of the weather station and the airborne DAS raises concerns of system integrity, compatibility and FCC regulations.

Complete integration of the systems depends upon the ground weather DAS's ability to be transparent to the airborne DAS. That is, the process of data transfer from the ground DAS to the airborne DAS is passive. One way to accomplish this is to utilize a data format the airborne DAS can acquire and "inject" the weather data into the airborne DAS using that data format. To the airborne DAS it is simply another aircraft parameter.

Now, an unusual situation arises when considering the ground DAS as the remote location and the aircraft DAS as the observation point. It becomes necessary to telemeter the ground weather data to the aircraft, place the weather data on the aircraft DAS Pulse Code Modulation (PCM) data stream and then telemeter all the aircraft data to the ground observatory for processing. It sounds long and drawn out, but the end result is clean. One FCC license is required to telemeter the data from the aircraft to the ground observatory. It is undesirable to use another license for transmitting the ground weather data to an aircraft system that is just going to transmit the data again. It is advantageous to use spread-spectrum technology (FCC part 15 does not require a license for spread spectrum transmissions within the specs) to transmit the ground weather data to the aircraft.

Utilizing all these techniques leads to the concern of compatibility. A completely integrated system will comprise of total compatibility with all devices in the system. With all things considered, the system works as follows. The ground weather DAS produces RS-232 (ASCII, comma delineated) data that is sent to an RF, spread-spectrum modem. The modem transmits the data to another RF, spread spectrum modem in the aircraft. The airborne RF modem decodes and sends RS-232 data to a processor that converts the RS-232 (ASCII, comma delineated) data to ARINC-429 data. The airborne DAS acquires the data as an ARINC-429 parameter and adds it to the PCM data stream for transmission to the ground observatory.

SYSTEM DEVELOPMENT

As with most data acquisition systems, the weather station has analog input ports (single-ended and differential), digital serial ports, control ports and excitation output ports. The weather station DAS was designed specifically to measure air temperature, wind speed, wind direction, relative humidity and barometric pressure. Therefore, its operating system and accompanying software provides specific signal conditioning control options for those sensors used in measuring the above mentioned weather parameters. For example, the relative humidity probe is connected to a differential analog input port on the DAS and within the software used to acquire the data are specific commands for port location, sensitivity (resolution), excitation voltage and storage address. Whereas, the digital compass is connected to a digital serial port, data is acquired with communication control (Hayes format) and memory location assigned.

Regardless of how the data is acquired, compilation to a common format is appropriate if telemetry is desirable. Again most data acquisition systems accomplish this task by "sensing" the data, quantifying the data and storing the data in memory. In most cases this is some A-D converter with sample and hold circuits and timing control. The weather station performs similarly and outputs the data in binary format. The binary format is converted to RS-232 format so that it is compatible with most computer peripherals.

The RF modems were selected because of their capability to accept RS-232 signals and transmit the data using spread spectrum technology. Spread spectrum incorporates a modulation technique that spreads the energy being transmitted over a very wide bandwidth. This technique reduces the power density of the transmitted signal, thereby making the signal invisible to other signals occupying the same spectrum. The receiving unit reverses the spreading process and demodulates the signal to obtain the information. The reversal process also suppresses undesired signals in the receiver. The combination of spreading and de-spreading makes the spread spectrum system one that imparts or accepts little interference. FCC Part 15 of the CFR authorizes the unlicensed operation of spread spectrum transmitters within the 915 MHz, 2450 MHz and 5800 MHz frequency bands. The RF modems selected transmit on 915 MHz and adhere to the specifications called out in FCC part 15 of the CFR.

Additional processing power is required in the airborne system to convert the received RS-232 data format to ARINC-429 format. The conversion process is accomplished using an airborne PC-type computer, software and an RS-232 to ARINC-429 adapter. The RS-232 to ARINC-429 adapter was selected due to the flexibility of software applications. This adapter allows for custom designed programs to interface data to the adapter.

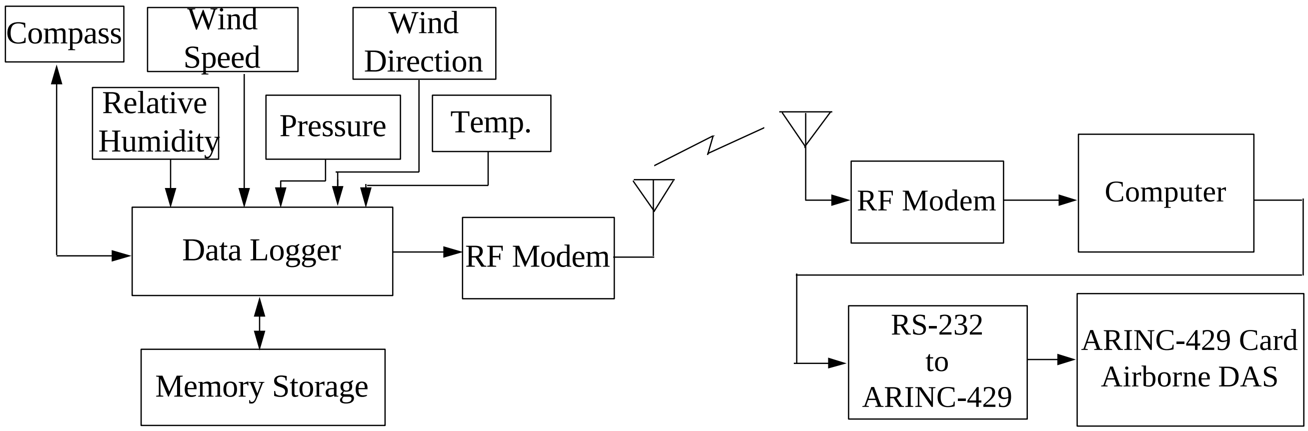

Figure 1: (a) block diagram of ground weather DAS, (b) block diagram of airborne DAS

SIGNAL FORMAT, FLOW AND TIMING

Once the weather station has been programmed there is no need to communicate with it. Therefore, the weather station is set-up on location, turned-on and left to transmit data. There is no handshaking that occurs between the ground weather station, RF modem and the airborne RF modem. The weather station samples all the weather parameters once every second except for barometric pressure which is sampled every thirty seconds. The weather station stores the data in an on-board, non-volatile memory storage module and sends the data to an RS-232 interface.

The modem receives the RS-232 data and when its packet is full, modulates and spreads the spectrum for transmission. The link between the weather station and RF modem is asynchronous (looks for start and stop bits only). Data is continuously being sampled and sent. Any delay (other than inherent gate delays from hardware) is based upon the packet size. The RF modems have been programmed for a packet size of 64 bytes. The total number of bytes used to represent one sample of all the parameters far exceeds the packet size and therefore data is continuously being sent.

The airborne RF modem reverses the spreading of the signal sent by the ground RF modem by matching the pseudo-code with which the spectrum was originally spread. The signal is then demodulated and the RS-232 data is placed at the com 1 port of the airborne computer. A software program was written to read the com 1 port of the airborne computer, strip the data parameters out of the ASCII comma-delineated data file, assign octal labels to each parameter and send the data to the RS-232 to ARINC-429 adapter via com 2 port. Again the link between the RF modem and airborne computer is asynchronous and continuous. The RS-232 to ARINC-429 adapter is set in transmit mode only (again, no handshaking) and transfers the data at 57,600 bps. The data is acquired on an ARINC-429 data card in the airborne DAS which is set to acquire data at 100,000 bps.

The format for communication between the ground weather DAS, ground RF modem, airborne RF modem and com 1 port of the airborne computer is 1 start bit, 8 data bits, 1 stop bit, no parity and set to 9600 BAUD. This is to ensure that asynchronous communications are successful between those components.

The airborne computer can process the data much faster than is being supplied at the com 1 port and is capable of transmitting the data via com 2 port at 115,200 bps. Note that since it is RS-232 format and a signal is in one of two states at any given time the baud rate and bps are the same. An RS-232 serial port requires 10 bits of information to transfer one byte of data. At a maximum of 115,200 bps the maximum theoretical throughput is 11,520 bytes per second. The ARINC-429 channel is set to acquire data at 100,000 bps and this equates to 11,111 bytes per second (ARINC-429 data is 32 bits long and an ARINC-429 word can only be transmitted once every 36 bit times). As stated above, the byte transfer rates of the com 2 port and RS-232 to ARINC-429 adapter are close and any burst in data is smoothed by the adapter's buffers. Since the RS-232 to ARINC-429 adapter is set to transfer data at 57,600 bps no overflow of data is expected.

The entire system operates in such a manner that data transfer is optimized by matching the baud rates of the weather station output port to the ground and airborne RF modems and in turn letting the airborne computer process the data as quickly as possible for throughput to the ARINC-429 channel. Regardless, any delay is tolorable due to the fact that under most test conditions weather parameters are not the concern of safety. Minimizing data drop-outs and maintaining the overall integrity of the data is the most important issue for a successful system. It is important to remember that telemetering the weather data is for ease of data processing, analysis and presentation not because engineering has a need for real-time analysis. The fact that it can be observed during real-time analysis is simply a secondary feature.

TEST APPLICATIONS

The system has recently been used in an aircraft certification program to document weather conditions during engine performance testing, specifically engine inlet distortion and recovery analysis. Although the testing was performed at an airfield that was equipped with an on site weather station, it was important to acquire weather data as close to the aircraft as possible. This meant placing the weather station in close proximity to the aircraft and telemetering the data to the aircraft DAS. Again, telemetering the data is for ease of documentation, testing and analysis.

The purpose of the engine performance testing was to determine the total inlet pressure recovery and total inlet pressure distortion. Test conditions for ground testing call out specific wind speed maximums and directions. For example, a power setting of 20% N1, wind speed of 20-25 knots with a right crosswind is one test condition. The direct correlation of the measured N1, pressures at the inlet and weather data allows the engineer to analyze engine performance with a higher degree of precision. The old days of assuming that the wind direction and wind speed were steady-state over a lengthy period of time (sometimes samples were taken every 5 minutes), induced a sense of uncertainty about the data. Now, at least the engineer has the actual raw data sampled at 1 hertz. If the calculations warrant an averaging or smoothing of the data, that is determined during post-processing.

Initial Data Load - No Modifications Made							
RUN # 004 -							
Time	ENGVIBL	ENGVIBR	HDG_1	N1L	N2L	PSIR01	PSIR04
HH:MM:SS.SSSS			DEG	%RPM	%RPM	PSI	PSI
13:46:05.8	NORMAL	NORMAL	-90.1751	24.3235	55.8291	-6.60E-03	-7.98E-02
13:46:06.0	NORMAL	NORMAL	-90.0872	24.225	55.9255	-6.60E-03	-7.98E-02
13:46:06.2	NORMAL	NORMAL	-90.0872	24.3235	55.9255	-6.60E-03	-7.98E-02
13:46:06.4	NORMAL	NORMAL	-90.1751	24.3235	55.9255	-6.60E-03	-7.98E-02
13:46:06.6	NORMAL	NORMAL	-90.1751	24.4219	56.0218	-6.60E-03	-7.98E-02
13:46:06.8	NORMAL	NORMAL	-90.1751	24.3235	55.9255	-6.60E-03	-7.98E-02

Time	ZWSBATV	ZWSBRPRS	ZWSRLHUM	ZWSSAT	ZWSWNDDR	ZWSWNDV
HH:MM:SS.SSSS	VOLTS	INHG	%	DEGF	DEG	KNOTS
13:46:05.8	12.7905	28.2841	39.8438	20.7813	172.806	19.2388
13:46:06.0	12.7905	28.2841	39.8438	20.7813	172.806	19.2388
13:46:06.2	12.7905	28.2841	39.8438	20.7813	172.806	19.2388
13:46:06.4	12.7905	28.2841	39.8438	20.7813	172.806	19.2388
13:46:06.6	12.7905	28.2841	39.5313	20.7813	177.2	22.2889
13:46:06.8	12.7905	28.2841	39.5313	20.7813	177.2	22.2889

Example 1: Data from engine performance testing

Example 1 shows airborne DAS data acquired during a test run with the data filtered at 5 samples a second. It is important to note that the weather parameters are updated every second due to the sample rate of the program, therefore when all the parameters are sampled at a higher rate, repetitive weather data is expected. The data in Example 1, shows that the aircraft was positioned at -90.1751 from magnetic north (HDG_1) while the wind was from 172.806 magnetic north (ZWSWNDDR). Therefore the aircraft is experiencing a 19 - 22 knot, 90 degree crosswind (ZWSWNDV). The engineer will correlate the weather data with the pressures (PSIR01, PSIR04) and engine rpm (N1L and N2L) to best determine total inlet pressure recovery. Another important aspect for using the weather DAS for this type of testing is to better determine if the test conditions are being met. The aircraft DAS has a screen that can display real-time data to the pilot. The pilot can see the correlated data and determine if each test condition is being met.

The system has also been used during airfield performance testing where wind speed and direction are critical in determining the performance of the aircraft. During these tests, the weather station is placed in a centralized location or expected touchdown and takeoff points adjacent to the runway. Again, the data is correlated with other significant parameters to allow the engineers a higher degree of precision in the analysis.

CONCLUSION

The integration of the ground weather DAS and the airborne DAS has proven to be successful and a useful system for engine and airfield performance testing. The motivation of the design was the fact that it is very undesirable to have many data acquisition systems from which to process data. The integration of the two systems was unusual in the fact that the systems are remote to one another. All of the components of the systems were integrated successfully by utilizing telemetry and controlling the signal format , flow and timing. Feasibility and economical concerns were addressed by utilizing spread-spectrum technology and simple interface components for data transformations.

ACKNOWLEDGMENTS

Jeffrey L. Fetter, Senior Engineer, Bombardier Flight Test Center

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