Helicopter Slip Ring Replacement System

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ABSTRACT

Most helicopter programs require the acquisition of parameters from the rotating systems. Historically, these systems made use of electromechanical slip rings for the transfer of power, control, and data from within the helicopter's cabin to the rotating hardware. Slip rings are primarily used in dedicated instrumentation vehicles and are not commonly used in production platforms that may require instrumentation of the rotating systems for in-service load and fatigue monitoring. Additionally, the use of slip rings requires time and money to integrate the hardware and equipment into the aircraft in order to perform rotor data acquisition. The time needed to perform modifications to transmissions and drive trains plays a big factor in the increased costs of aircraft development. Less intrusive installations would minimize the need for mechanical changes and would improve the time needed to install the instrumentation.

This paper describes a wireless system approach to perform the test without the slip ring, and provides performance data that validates this new method of instrumenting unobtrusively to save time and money without sacrificing data integrity.

Key Words

Bluetooth, PCM, Slip Rings, Wireless, Less Intrusive

Introduction

Helicopters have used HUMS (Health and Usage Monitoring System) for almost two decades. It is being used on production vehicles as a data acquisition system to detect usage and vibration information. It provides with the earliest indication of incipient mechanical defects that grow slowly over time. The HUMS assist greatly in reducing unscheduled maintenance, and extends the lifespan of many of the aircraft's systems. The HUMS system is primarily installed in the helicopter's cabin, and collects no data from the rotating system. Helicopter blades and other rotating subsystems receive scheduled maintenance and are being replaced based on the manufacturer's recommendations. These recommendations are derived from flight test data acquired from the rotor system, using slip rings and analysis. The most cost-effective way to replace helicopter blades and other components of the rotating system is by using a HUMS data acquisition system on the rotor(s). A rotor mounted HUMS system will provide early indication of rotor/blade fatigue, and will provide an "*elegant scenario where you don't have to replace components too early to compromise cost, but you don't replace them too late to compromise safety*"[1] . Additionally, the system could aid in troubleshoot rotor problems (instability, balance, etc) in the production fleet without the use of slip rings and would keep the aircraft in the fleet while testing is performed.

The challenge to retrofit and place data acquisition system on the rotors in an existing fleet of helicopters is the lack of slip rings between the rotor(s) and the cabin. This challenge requires the development of a data acquisition system that transmits its data wirelessly to the cabin, and a power battery or a power harvesting device to power the rotating acquisition system. The first phase of the development includes the wireless data acquisition system mounted on the rotor and transmits its data to the cabin using Bluetooth wireless communication as well as providing the data through slip rings for comparison and latency evaluation. No power battery or power harvesting device was used at this current phase.

The rest of the paper will cover the system approach, several elements of the design, time synchronization, Bluetooth, antenna considerations, and test results.

System Approach

The goal is to develop a wireless instrumentation system suitable for meeting requirements of rotor mount acquisition system demonstrations, and a dual use of the system during flight test without slip ring as well as a HUMS system for the production fleet.

The system approach utilizes decades of flight test experience in the instrumentation of helicopter rotating systems, and enables the designers to develop system requirements that must meet the following key criteria:

- Comply with data and environmental requirements for rotor demonstrations and in-service use with this system.
- Develop a functional solution utilizing Bell's internal resources and outside contractor with proven wireless applications for harsh environment.
- Demonstrate system functionality on a rotating test stand using both wireless and the traditional slip-ring for a base-line comparison
- Test HUMS sensors using the Wireless Slip-Ring

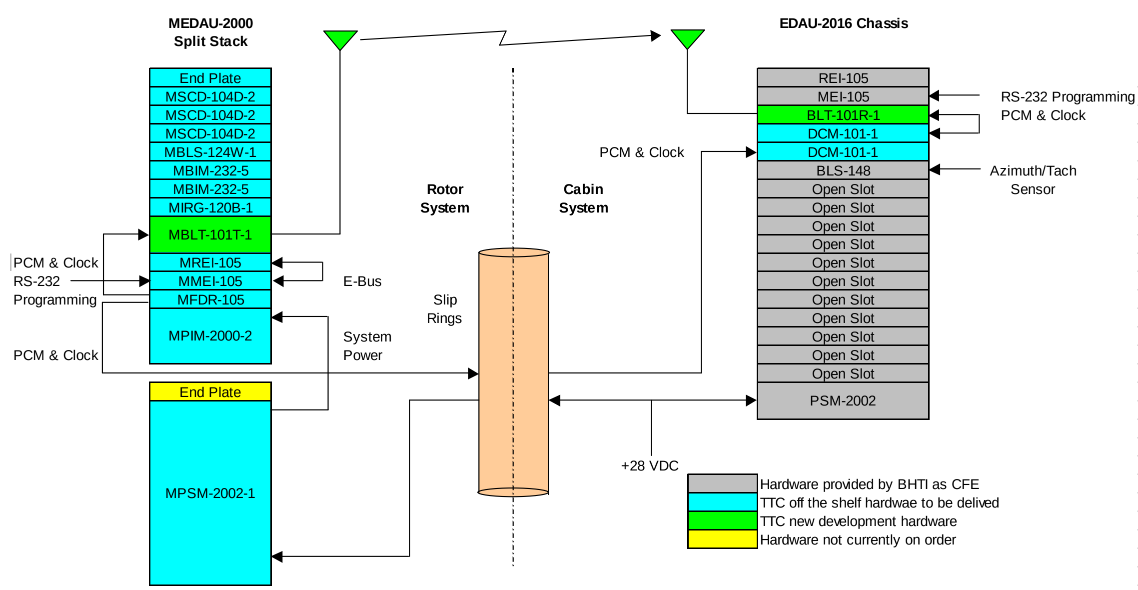
System Description

The Slip Ring Replacement System (SRRS) shown in figure 1 and 2 consists of a PCM-to-Bluetooth Converter (MBLT-101T-1) module mounted as part of a Standalone PCM Miniature Enhanced Data Acquisition Unit that is mounted in the rotating system of a M407 rotor. This module communicates data, time, and configuration with another card that converts Bluetooth-to-PCM (BLT-101R-1) installed as part of a unit in the non-rotating system (cabin). The same data transmitted over the Bluetooth was also provided over the slip rings for baseline comparison of data latency, data throughput, and link analysis. The rotating acquisition system acquired data from multiple strain gauge channels, a fiber optic strain gauge system using high speed RS-232/422 interfaces, and several discrete channels. Bluetooth 2.0 operates at little less than 1Mbps. The Bluetooth packet protocol used for communication between the rotating system and the cabin included overhead data, data payload, allowance for retransmissions, and periodic time synchronization which resulted in a maximum effective useful data rate of 300Kbps. This data rate was well within the PCM data rates of the rotating system.

In order to maximize efficiency of the wireless link, data are transmitted over the Bluetooth data link in packets of varying size depending on the data rate. At low data rates, Bluetooth packet size is kept fairly small to provide acceptable latency, while at higher rates, the packet size increases to provide higher data throughput.

As packets are received, payload data are stripped from the packets and added to a first-in, first-out buffer (FIFO). When data transmission is first initiated, this FIFO fills to a pre-determined level before PCM data output starts. Once PCM data output begins, the "fullness" of the FIFO is used to exert fine control of the PCM data output rate. This approach has two benefits. Delays in the Bluetooth link are averaged over a long period of time, providing a constant average latency of around 72ms. Additionally, the PCM clock rate at the receiver unit in the cabin remains essentially constant and synchronized with the data transmission rate of the rotor unit. An observer looking at the output data would see no difference between the received wireless and slip ring data streams other than a constant latency.

Figure 1. System Architecture



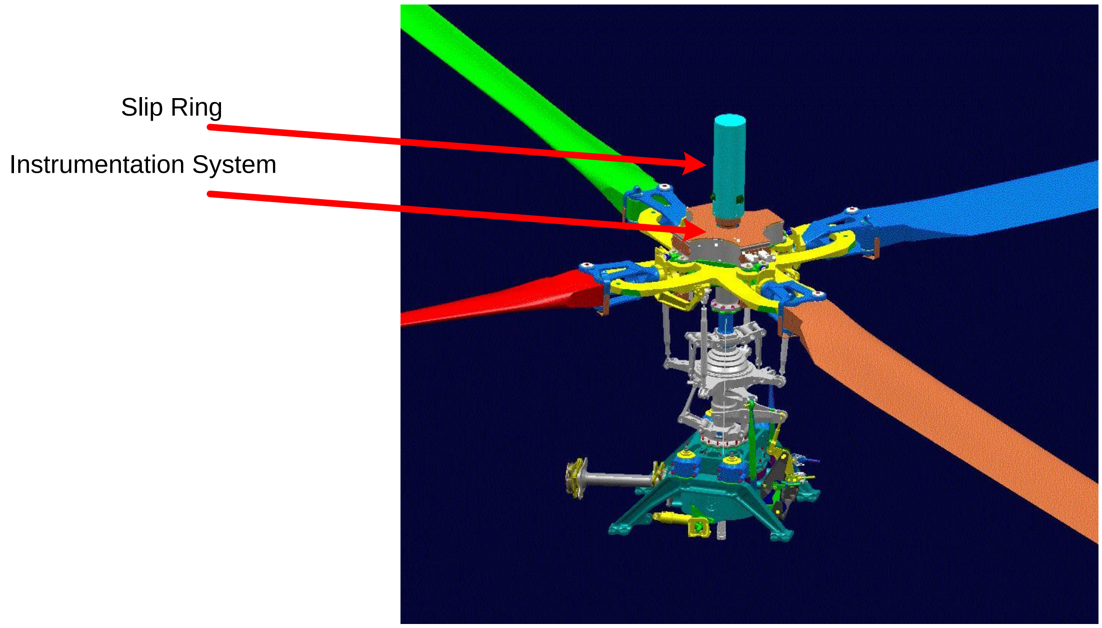


Figure 2. Slip Ring and Instrumentation System

Bluetooth

The choice of Bluetooth was based on TTC's experience with this technology for use with wireless sensors [2][3][4] operating at a data rate of 300Kbps. We used Bluetooth [5] 2.0 class II that provides 100 milliwatt of RF power, and operates at 921 Kbps. The effective throughput rate is lower (just above 300Kbps) due to data packet overhead, potential retransmissions, and control packets. The 300Kbps proved to be sufficient for the application with adequate spare bandwidth to add more sensors in the future or to increase the sampling rate of the current sensors.

Tests have been conducted in the lab, as well as in the actual installed platform, in order to better understand the capabilities and challenges associated with the use of COTS wireless transceivers in aircraft data telemetry applications. For example, aircraft telemetry S band transmitters operate from 2.2 – 2.45 GHz while Bluetooth devices operates between 2.4 – 2.483 GHz. Sharing of this frequency band may lead to serious loss of Bluetooth data due to receiver saturation whenever the aircraft S band transmitter is in operation. An interference test was performed with an S Band transmitter and the Bluetooth transceiver. The S Band transmitter was set to a maximum frequency of 2.37 GHz, 8 Watts of output power, and located 10, 5 and 2.5 feet from the Bluetooth transceiver. No degradation in the Bluetooth was observed.

Line of sight is another issue in wireless technology. When implementing a low power Bluetooth wireless data link from one part of the aircraft to another, it is highly desirable to have an uninterrupted line of sight from transmitter to receiver. When this is not possible, the quality of the data link may suffer. Bluetooth Type II operates at a distance of up to 30ft within line of site. In our application, the installation was well within the 30ft, however installation of the antenna in the rotor system implied no line of site during a portion of the rotation, see figure 3.

The Bluetooth antennas were installed to simulate the locations for a flight aircraft and to maximize line of sight. Initially, antenna masking was a big concern due to rotation of the rotor. However, testing revealed masking was not an issue.

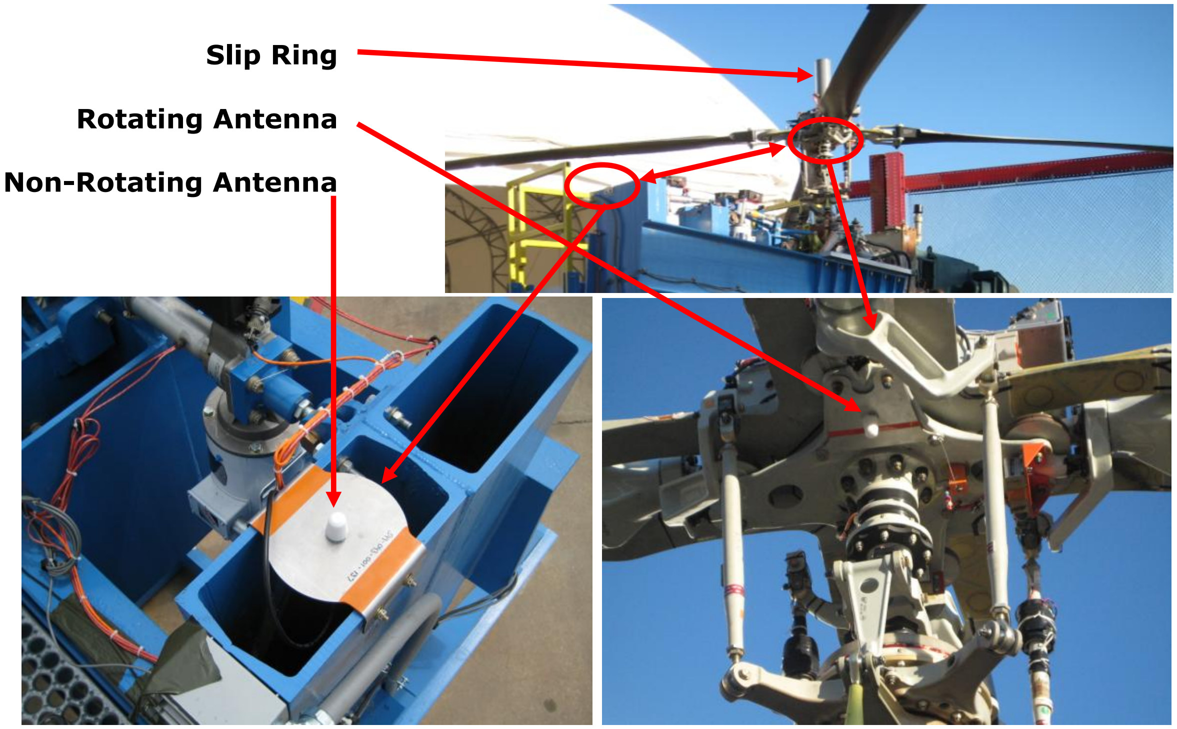


Figure 3. Bluetooth Antenna Locations

A standard flight test instrumentation slip ring was used for the baseline serial PCM for comparison to the Bluetooth PCM.

Instrumentation system packaging

The rotating PCM encoder was repackaged in an aircraft enclosure to optimize interface to the aircraft's rotor system as shown in figure 4. Pre-existing designs also supported the standard instrumentation slip ring and adapter hardware which allowed for the concurrent testing of the Bluetooth PCM and Slip Ring PCM. The acquisition unit was split between the acquisition modules and the unit's power supply due to mechanical balance requirements. The Bluetooth transceiver and electronics was packaged as a plug-in module to the acquisition system (similar to all acquisition modules) with external antenna wiring.

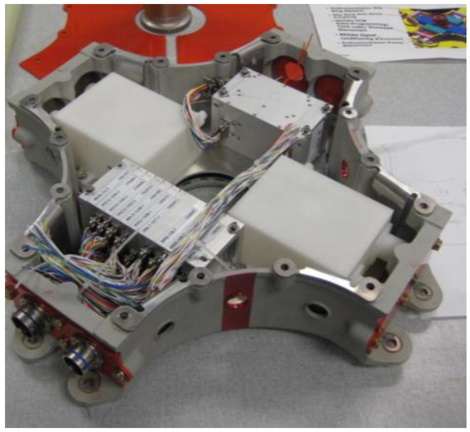
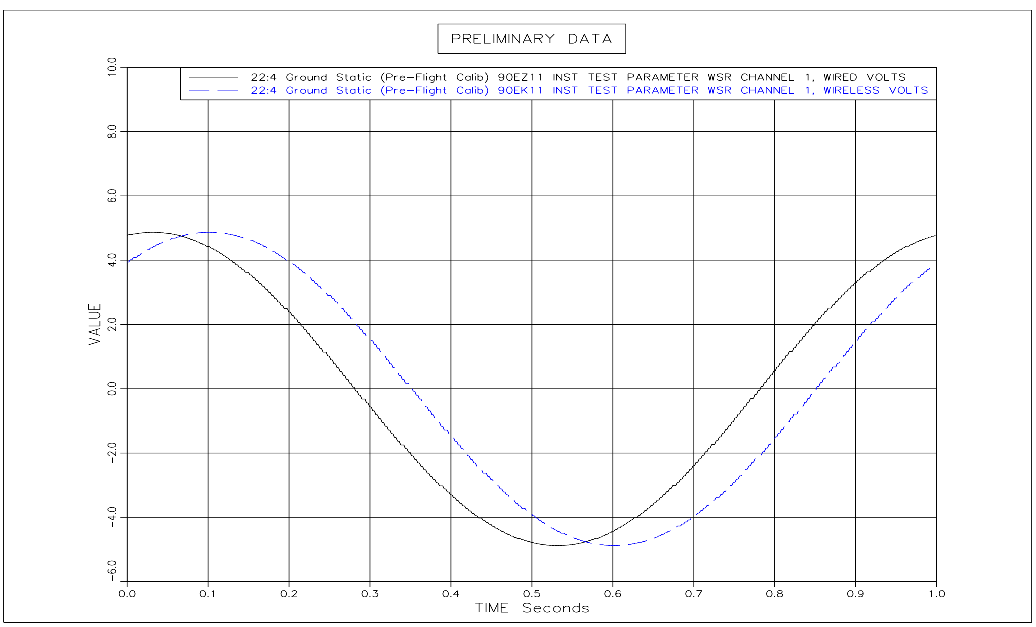


Figure 4. Instrumentation system packaging

Test Data

The test was done using a rotor system mounted on a rotor stand in order to verify the wireless data against slip-ring data. During testing, the sensor data measurements were identical between the wired PCM through the slip ring and the Bluetooth PCM. Data latencies between the wired PCM and the Bluetooth PCM were consistent and stable. The latencies were 71 to 72 mSec. The RF Link was stable and reliable and did not show any dropouts. The wireless data was converted to PCM data in the cabin by the wireless receiver card. Both slip ring PCM and the reconstructed wireless PCM were monitored using PCM decom cards. The data showed that both PCMs never lost lock for both streams during the operation of the rotor stand.



Test signal – 1 Hz Sine (PCM to compare to the Bluetooth PCM)

Conclusions

The design and integration of a wireless PCM system in a rotating system met the design goals. The data link stability and the data latencies were the biggest concerns. By characterizing the data latencies with its stability, this will allow time-aligning of the Bluetooth data to the non-Bluetooth data. This realignment is critical in the data analysis when comparing rotor loads, relative to the non-rotating loads.

Future testing of the system in a normal flight test environment will further prove the benefits of a wireless data system. Other interference issues would include RF transmissions in the area and aircraft avionics system interference. Once the use of slip rings is eliminated, then a stable power source will be required to supply the wireless data system.

References

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[5] BLUETOOTH is a registered trademark of Bluetooth SIG, Inc.

Acknowledgement

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