Modeling and Simulation of Avionics LRU for System Health Management

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Abstract—The electronics systems that are being used in aviation industry are commonly summarized as avionics. Approximately, seventy years ago the first avionics devices used on aircraft are navigation and communication systems based on old gauge instruments and analog systems. Since then, the industry has evolved a lot and today the avionics systems require for new and smarter functionalities thus driving the overall aviation research to an exponential rate towards high grade avionics systems and architectures. In this paper, a complete investigation has been performed regarding to the maturity of avionics systems from different phases of the development. In this project the four LRU's are considered with which each LRU's having different input parameters with different sampling time. Based on the time samplings the arrays of data are sent serially without any time delay. Once the arrays of data are sent out as output it goes to the embedded system which consists of data concentrator and the reasoner. The data are collected here and then sent to the micro controller through data bus and finally the output is displayed on the PC. Mathwork SIMULINK can be used for coding part and the algorithms are implemented with Simulink blocksets. The outputs are viewed on the scope blockset based on the input signal given to each LRU. The output is compared to the required output.

***Index Words*— Avionics, LRU, System Health Management, Simulation.**

I. INTRODUCTION

"Aviation and Electronics" are the source for Avionics. This system used on aircraft, artificial satellites, and spacecraft. Avionics engineering is the art of electronically integrated which include navigation, communication, radar system, the display and management of multiple systems that are fitted on to aircraft to perform specified functions.

The avionic system architecture refers to the avionics instruments layout in the cockpit which is a typical location for avionic equipment, including control, monitoring, communication, navigation, weather, and anti-collision systems.

There has been an achievement against centralized control of the multiple complex systems fitted on to the aircraft that includes engine monitoring and management. HUMS are integrated with aircraft management computers to give upholder early warnings of parts that will need restoration. The combined modular avionics concept proposes an integrated architecture with application software compact beyond a cluster of common hardware modules. The fourth generation jet fighters and the latest generation of airliners use it.

The aim of health monitoring system is to detect and diagnose commencement of any bug, to analyse its effects and it also helps to trigger maintenance work flow in order to maintain safety of the aircraft. Health Monitoring systems are employed on both structures and systems.Structural Health management essentially looks after structural integrity by online substantially monitoring of damage growth and assessing remaining useable life.

System Health monitoring surveillance after functional form and any degradation in the performance triggering maintenance task or replacement of affected LRU.

The Avionics Health management consists of a CNS system, different types of displays, Radar systems and Remote Processors which are connected through the data buses. This paper mainly concentrates on the health condition of the few avionics subsystems.

The specified time sample between the signals is given as the input to the LRU. Based on the time sample the health of the avionics subsystem which is a part of an avionics system is monitored. The sampling of time are implemented only for the few avionics system and this can be extended to other subsystems which includes navigation, display system, radarsystem, surveillance system etc., which are included in avionics system, which are equally important for the safe flying of an aircraft. For all the different systems we can implement the same technique that we used for ADF, RA, ADCU and AOA subsystems and check the required output to the given samples.

II. ARCHITECTURE

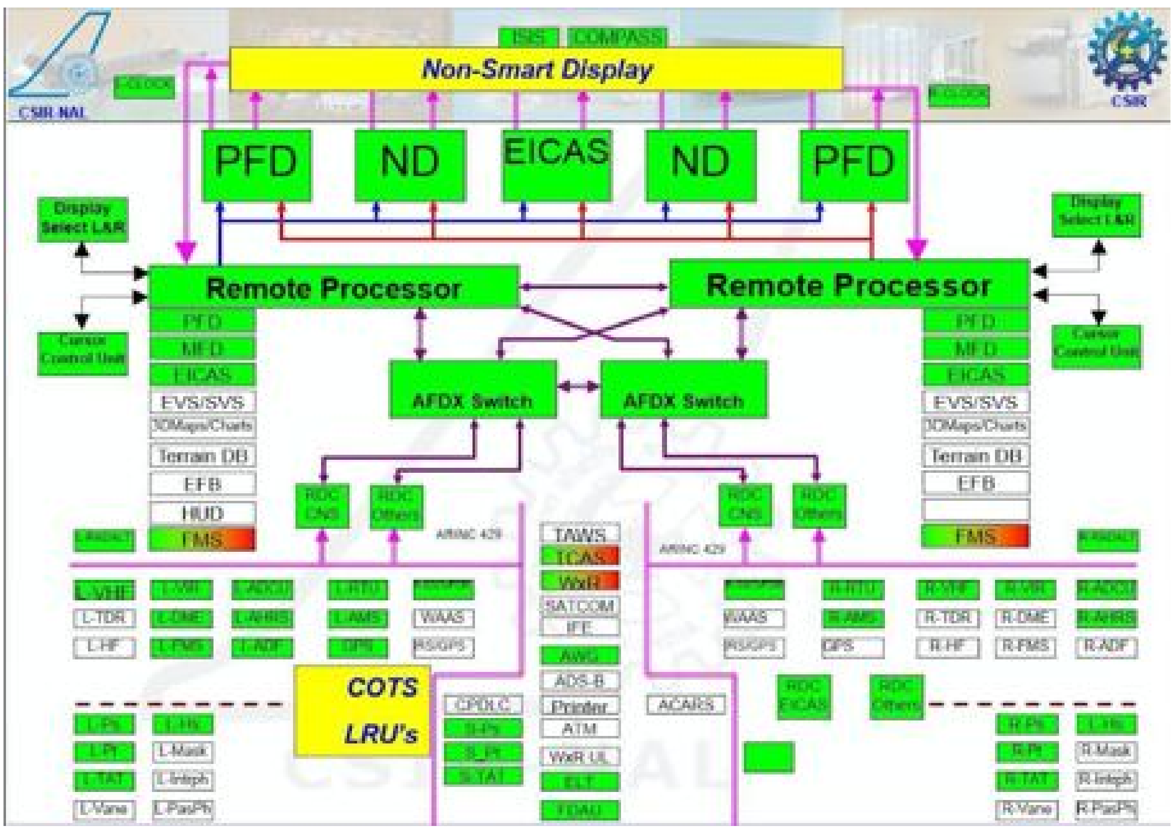

Fig. 1: Architecture of Avionics Health Management System

Avionics of general aviation aircraft consists of typical systems like communication, navigation, display, radar, engine indication and data acquisition and recoding systems. Thesecan be realized in federated as well as integrated architectures. The LRUs requirements for avionics sub-system depend on the certification standards like FAR 23 or FAR 25. The whole cycle of architecture definition, integration, testing and means of compliance of the complete suite is the major activity in any new aircraft development programme. All these system are connected through the data bus [1].

This process can be segregated to three parts. Firstly the input output simulation is done to verify the serial communication in LRU's. Secondly, the simulated logic in the embedded system is implemented. Lastly, summary and logging of the data is sent to the PC. The Embedded System consists of a Data Concentrator Unit, reasoner and the micro controller.

The Data are transferred through the data Buses for sending of data from one system to another system and an UART port as both receiving and sending of data. Data Concentrator Unit is a microprocessor based controller that receives different inputs which are in different formats and being carried out for processing. Then format them into common digital data formats by various aircraft systems. The DCU design processes many digital communication protocols including ARINC 629, ARINC 429 and Ethernet.

The DCU interfaces with various avionic systems and aircraft subsystem components. The DCU also interfaces to other systems using ARINC 429 and Ethernet data buses. It can perform data scaling, offsets, range checking, data formatting and Built In Test functions. The DCU also provides output capacity for subsystem component control and crew warning and alert indication.

Real-time safety-critical systems are currently engineered in a deterministic and conservative fashion. Avionics has one of safety critical real- time system in an aircraft which manage navigation, communication, fight control and data display system. The avionics malfunction will cause flight fail of the aircraft and can lead to disasters.

Avionics Architecture- Along with the improvement of technologies, the industries have rapid growth towards integrated architecture called Integrated Modular Avionics(IMA). Over a certain period of time there has been a tremendous growth in this technology which emerged out with reduction in weight, volume and in the development process.

Traditionally avionics systems are more functionality centric with dedicated hardware and software. Aircraft architecture plays an important role in robustness of the system. Avionics systems are classified as three major sections they are Federated Architecture, Integrated Architecture, and Distributed Architecture.

Federated Architectures- Federated architectures are of 1980’s technology and use individual LRUs. Functionalities are realized by dedicated hardware boxes (LRUs) having independent hardware and software resources. Fault management, fault containment and the electrical power requirements are met individually in LRU level. This architecture do not share any resource across the LRUs except the communication data bus externally. A federated system like avionics system having independent hardware units for each of the function that need to be carried out.

Integrated and Distributed Architecture- Present day integrated architectures has tremendous growth and used in aerospace field. This architecture entertains different avionics functionalities on the same hardware using supported real-time operating system. But the application software differs from one each avionicssystem.These systems are called integrated modular avionics (IMA). Currently the architecture ismore of distributed integrated architecture than just integrated architecture. The avionics cabinets are distributed across aircraft for various sub-systems and connected by an integrated global digital bus AFDX.

III. LRU’s OF AVIONICS SYSTEM

A line-replaceable unit, lower line-replaceable unit, line-replaceable component, or line replaceable item is a modular component of an airplane, ship or spacecraft (or any other manufactured device) that is designed to be replaced quickly at an operating location.

Air Data Computer Unit (ADCU)-In this section we shall be considering all of the functions of the air data computer separately inorder to study their history, purposes and principles of operation

The main measurements to be considered are:

a) Air speed (indicated, true and Mach number)
b) Altitude
c) Temperature
d) Angle of Attack

Air speed-Air speed is probably the most important single piece of information the pilot needs. Virtuallyevery phase of flight is conducted at a prescribed airspeed or range of airspeeds [2].

Altitude-The second most important piece of information is altitude.

Uses of altitude information:

a) - by the air traffic control system to provide vertical separation between aircraft.

b) - to avoid terrain.

c) - to convert indicated airspeed to true airspeed.

d) - to control the pressurization system in the aircraft [2].

Temperature- Temperature information is used to compute Mach number and true airspeed and to indicatewhen external conditions are such that icing is likely [2].

Angle of Attack-The angle of attack is used primarily to drive the stall warning and stall prevention systems.

Older types of aircraft have a distinctive pattern of behaviour as they approach the stall but many modern aircraft do not. Also, in T tail aircraft it may not be possible to recover from a stall. Thus artificial means of providing warning and prevention are required.

At a certain angle below the stall angle, a stick shaker is activated. This is similar to the natural stall warning which occurs in older aircraft (due to turbulent airflow over the horizontal stabilizer and elevators from the stalling wing). If the pilot does not take appropriate action to decrease the angle of attack and if it increases, a stick pusher forces the stick forward to prevent the stall from occurring [2].

ADF-It has the major advantage over a VOR in that reception is not limited to line of sight distances.

The LF signals follow the curvature of the earth, and thus the maximum distance that an ADF is usable depends only on the power of the beacon. Four types of ADF Indicators those are fixed

Compass Card, Rotatable Compass Card, Single-needle Radio Magnetic Indicator, Dual-needle Radio Magnetic Indicator. The most important concept in ADF navigation is that the needle always points to the station.

There are three implications to this:

First, when tuned to an ADF station for homing, tracking, intersections, holding or an approach, you never have to touch the system. Unlike the VOR, there's no OBS to think about, no need to "twist" anything in station passage or at any other time. This makes the ADF much simpler to use.

Second, with help of ADF you will always know the aircraft's location in relation to the station.

Third, ADF orientation is much simpler than VOR orientation. With an RMI the head of the ADF needle always indicates the bearing to the station. Simply turn to the heading under the arrow head to fly towards the beacon [2].

Radio Altimeter-Radio altimeter is used on aircraft, measures altitude above the terrain presently an aircraft orspacecraft by timing how long it takes a beam of radio waves to reflect from the ground andreturn to the plane. This type of altimeter provides the distance between the antenna and theground directly below it, in contrast to a barometric altimeter which provides the distance abovea defined datum, usually at sea level. Radio waves are transmitted towards the ground and thetime it takes them to be reflected back and return to the aircraft is timed. Because speed, distanceand time are all related to each other, the distance from the surface providing the reflection canbe calculated as the speed of the radio wave and therefore the time it takes to travel a distance areknown quantities. Radar altimeters normally work in the C band, Ka band and S band is used formore advanced sea-level measurement [2].

Angle of Attack (AOA)-Angle of attack is the angle between the body's reference line and the oncoming flow. The liftcoefficient of a fixed-wing aircraft varies with angle of attack. Increasing angle of attack isassociated with increasing lift coefficient up to the maximum lift coefficient, after which liftcoefficient decreases. As the angle of attack of a fixed-wing aircraft increases, separation of theairflow from the upper surface of the wing becomes more pronounced, leading to a reduction inthe rate of increase of the lift coefficient [2].

Avionics Buses- Data transmission is conveyance of information from source to destination. In analog avionicsdata transmission system, at least one pair of wire is required for each signal between the sourcesand destination. Hence, a typical point to point analog airborne network would require 10's ofpairs of wires. In digital data bus, analog signals are converted into digital equivalents, assignedunique address labels, multiplexed and transmitted down a single pair of wire which makes up adata bus, which can either be serial or parallel. Integrated digital avionics data bus allows datamultiplexing, transmission/reception and communication of on-board avionics data in modularavionics architecture. In vogue, data bus protocols are:

ARINC 429,

ARINC 629, ARINC 664,

ARINC 818, MIL-STD 1553, MIL-STD 1773, Commercial Serial Digital Bus (CSDB) and

Avionics Serial Communication Bus (ASCB) [3].

IV. AVIONICS SUBSYSTEM

An input of +28V is given to all the 4 LRU's. It also has a redundancy of +28V. The LRU’s are ADF, RA, ADCU and AOA. The data of each LRU's are transmitted tothe embedded system through ARINC 429. The Embedded system consists of DCU, Reasoner and micro controller. The data from DCU is sent to micro controller using ARINC 429. The interactions between the Reasoner and the micro controller will be using UART. The communication between the PC an the Micro controller is done using UART interface.

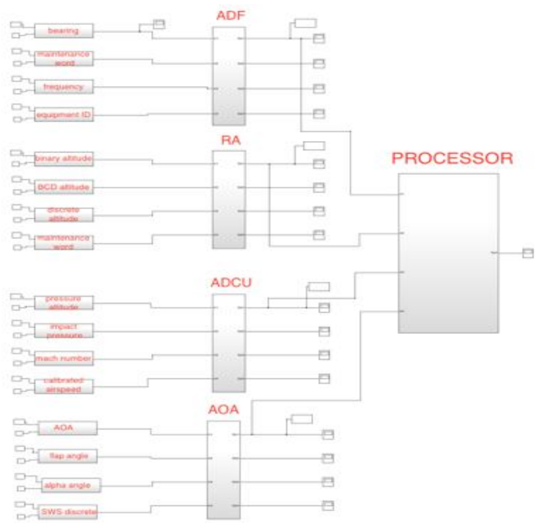

Fig. 2: Architecture of Avionics Sub- System

For the simulation purpose four different LRU’s like ADF, RA, ADCU, AOA with each LRU’s having four different parameters and sending the data with different update rates are considered.

V. RESULT

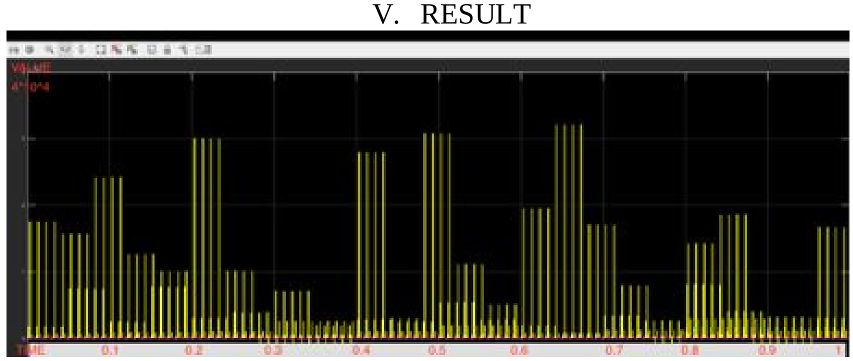

Fig. 3: Output Signals

The graph is plotted as time in x-axis versus data in y-axis. The color pink represents the label and the color yellow represents the data parameter of each LRU.

Here the input given to the avionics subsystem is data parameters and labels with its time sample. Each data parameter appears in the output for every time after the time delay. For example parameter 1 of LRU 1 is bearing with the time sample of 0.05s.

Thus for every 0.05s the parameter bearing appears in the output. This is the same with all the parameters of all LRU's.

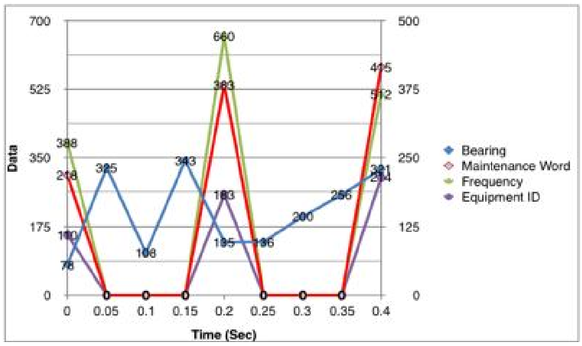

Fig. 4: Results of ADF

The figure clearly shows the data parameter and the label number depending on the given input. In ADF the output has four data parameters with four different label numbers. Bearing is appearing at every 0.05s, maintenance word, frequency, Equipment ID at every 0.2s.

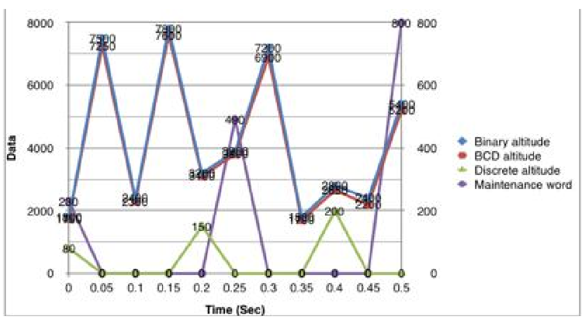

Fig. 5: Results of RA

The figure clearly shows the data parameter and the label number depending on the given input. In RA the output has four parameters with four different label numbers. Binary altitude and BCD altitude is appearing at every 0.05s, discrete altitude appears at every 0.2s and maintenance word appears at every 0.25s.

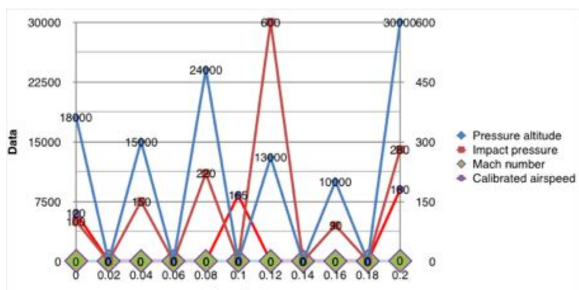

Fig. 6: Results of ADCU

The figure clearly shows the data parameter andthe label number depending on the given input. In ADCU the output has four parameters with four different label numbers. Pressure altitude and impact pressure is appearing at every 0.04s, Mach number and calibrated air speed appears at every 0.1s.

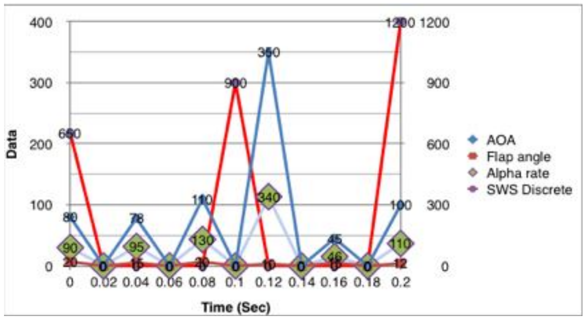

Fig. 7: Results of AOA

The figure clearly shows the data parameter and the label number depending on the given input. In AOA the output has four parameters with four different label numbers. AOA, flap angle and alpha rate is appearing at every 0.04s and SWS discrete appearing at every 0.01s.

VI. CONCLUSION

Health of an Avionics system is very important in the aircraft, as the failure of an aircraft causes hazards losses in the context with both those posing danger to vehicle occupants and those affecting the general publican's environment in which the vehicle operates. It is essential to enhance the reliability of an aircraft by deciding the health status of the whole aircraft system.

This includes safety, reliability and efficiency of the system. Hence this will bring forth the realization of condition based cost reduction and also aircraft maintenance. The paper demonstrates the implementation of Health Monitoring of few avionics subsystems.

The signal analysis routines are constructed using SIMULINK block diagram. Based on the timedelay the Health of the avionics subsystem which is a part of an avionics system is monitored.

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