Physical Considerations of Avionics

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Abstract

The Integrated Modular Architecture (IMA) has many physical, electrical, and optical hardware input/output (I/O) configurations. Discrete, twisted pair, or coaxial copper wiring forms most of the installed base operating at relatively slow speeds. Faster backbones operating at 10 Gbps on 850 nm multimode optical fiber have recently been implemented. A planned update to 14 Gbps or the recent 6 Gbps CoaXPress offer some relief from increasing capacity demands but neither solution can resolve current wiring density problems. A Network Object Architecture (NOA), enabled through an optical network, could utilize industry standard connectors and I/O building blocks while incrementally adding features and services.

Keywords: Input/Output, Integrated Modular Architecture, Network Object Architecture, fiber, optics

I. OVERVIEW

The need for more connected applications and services drives the telecom and datacom markets to increase network speeds by roughly 10× every few years. This increase in speed occurs in tandem to—but opposite of—the cost of the components within those networks, which may decrease 10× every few years. The lifecycle of optical components and semiconductors is much shorter than the lifecycle of an aircraft. This creates market turmoil for aerospace original equipment manufacturers (OEMs). Avionics do not need 10× speed increases; they need more systems and discrete links to accommodate industry standards. These standards take years to ratify and are required to maintain functionality across decades of diverse applications around the world.

Today's Integrated Modular Architecture (IMA) arose due to the legacy manufacturing process of building airplanes wire by wire. To improve that process, aerospace OEMs adopted electronic bays as the central locations for the IMA's standardized hardware. Although each system still came with its own unique requirements (and service contracts), this change improved manufacturing efficiencies over the discrete wiring assembly processes. Modern aircraft (e.g. the Airbus A380 and Boeing 787) witnessed further evolution of IMA with the implementation of an aerospace network protocol called Avionics Full Duplex (AFDX) to offer separate applications with support contracts over a single network.

The electronic bays in an IMA include board level I/O, box level I/O, and related wiring and connector standards. Again, this was an improvement in managing the complexity of the networking needs of a modern airplane. However, the benefit that this new standardization offered came with a growing problem: the incremental industry standard computing boxes all had separate wiring. That wiring had to occupy the same space in the airplane that was originally allocated for the initial systems. Even with AFDX's shared networking, the physical space for additional wiring became a bottleneck. The complexity and density of these additional wiring systems began to decrease the efficiency of the standards that enabled them. Wiring problems, such as the ones that plagued the A380 early on; the slow and unreliable availability of In-Flight Entertainment and connectivity systems, or the slow pace of aerospace sensor innovation, are signs that the IMA must evolve.

An avionic optical network that reaches all parts of an airplane will enable more applications; additional sensor and communication channels; faster, and protocol independent networks; and simplify wiring design and installation. This new network could use the circular, rectangular, or square connectors of today's (2018) IMA, but do so in a way that distributes the hardware and decreases some of the wiring density. This type of distributed network could also use optically-upgraded IMA computing boards, boxes, and chassis, but they might be smaller, lower power, run cooler, and be installed in several places throughout the airplane—not just the central cabinet. The avionic optical networks could also use existing fiber optic wires and termini; but have enhancements to make them carry more signals over the same fiber and be installed easier and faster. These components will then function in IMAs or enable distributed I/O in the form of subnetworks. These subnetworks become objects in the overall network and thus could be called a Network Object Architecture, or NOA.

II. PHYSICAL I/O

The computing boards used in IMAs perform application-specific functions such as data path switching, video or audio transmission, analog processing, and data recording from multiple sources. These boards run industry standard protocols such as MIL 1553, ARINC 429 (Serial), ARINC 825 (CAN), ARINC 664p7 (AFDX), and ARINC 818 (FCAV). The boards themselves can be in custom form factors but often have main computer boards in virtual machine environment (VME) footprints with fixed mobile conversion (FMC) standard pluggable modules. Additionally, IMA systems typically have an integrated I/O patch panel creating a central point where wiring starts or ends (input or output).

Copper cables are the basis of most avionics networks today (2018), because many system protocols are hardware-dependent where the physical wiring supports the application they perform. This tie-in has created an inflexible position which limits the growth and complexity of new features within an airplane. Fiber optic networking offers a variety of benefits over copper wiring; including a weight reduction of roughly 70%, a drastically smaller footprint, and inherent electromagnetic interference (EMI) properties. Furthermore, adding flexible protocols makes the use of fiber optics very appealing.

The Boeing 787 implemented a large-scale fiber optic network operating at 100 Mbps with the AFDX protocol. The network and fiber optic components closely resembled the copper equivalents they replaced. This resemblance isn't surprising considering the risk associated with implementing a new technology such as fiber optics that needs extra handling and maintenance. Fiber optics for this application saved weight (glass vs. copper) and enabled communication lines (fiber cables) to be run through non-standard data wiring areas that previously had installation limitations. The 787 has a traditional IMA with vendors such as Rockwell Collins and GE Aviation providing key computing boxes.

These computing boxes utilize ARINC standard I/O connectors with fiber optic termini. Fiber optic termini can be the same size as copper, thus reducing risk to the mechanical upgrade path. For example, there are size 16 fiber optic termini as well as size 16 copper termini; this means that a 4 position D38999 can accept either legacy copper or modern fiber optics (Fig. 1–5). Additionally, the same tools can be used throughout the existing installation process. The connectors are functionally identical; however, the tolerances of the fiber connectors are held tighter than their copper equivalents to provide a high-precision fit and to prevent light attenuation. The termini are attached to a glass cable with aerospace-grade epoxies (instead of solder as it would be for copper) and are wrapped in aerospace-grade jacketing that protects the glass while still meeting smoke and toxicity emissions standards.

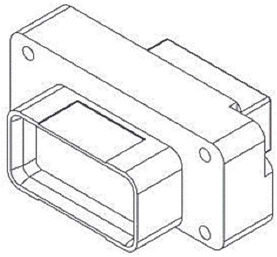


Fig. 1 *EPX Connector*

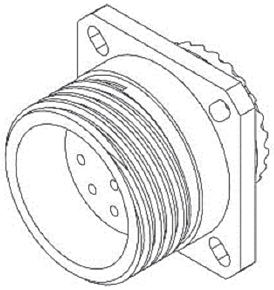


Fig. 2 *38999 Receptacle*

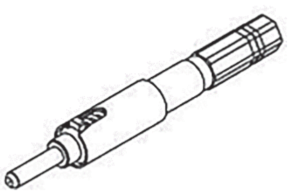


Fig. 3 *ARINC 801 terminus*

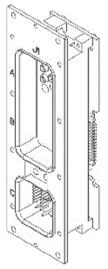


Fig. 4 *ARINC 600*

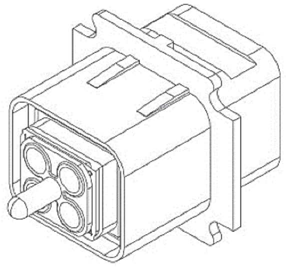


Fig. 5 *EN4165 Connector*

The optical fiber carries data in optical pulses. The data electrically originates from a microprocessor and travels to an optical transceiver that converts the electrical signals to optical pulses through a fiber interface connector. The transceiver can be installed either on a computing board or at the line replaceable unit (LRU) I/O connector. The most widely used optical signaling operates on multimode fiber at a wavelength of 850 nm. The multimode fiber has a ferrule inside the termini at the end of the cable which mates to another connector. The termini are installed into the transceivers and the box level I/O connector. From that connector, a wire or fiber cable runs through the aircraft usually with more than one interconnect or mated connector pair. The location and frequency of the interconnects are driven by the size and complexity of the aircraft itself.

The military standard MIL-STD-38999 connector (Fig. 3) is the dominant form factor, although there are several similar style circular connectors. A more recent standard is the General Purpose Rectangular (Fig. 6) (GPR), offering multiple configurations which include inside an ARINC 600 or mated to itself along the airplane cable runs. Furthermore, EN 4165, a European standard, offers a wide range of configurations along with a diverse number of vendors, thus leading to the belief that the use of this building block is growing internationally.

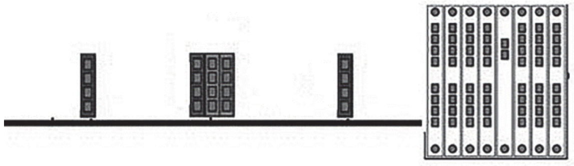


Fig. 6 *ARINC 836*

Single mode fiber offers larger optical link budgets over longer distances which could result in more complex network designs. However, the maintenance of single mode fiber is much harder than multimode because of its smaller core size (the area where light is transmitted) which is about one seventh that of multimode. This smaller core helps maintain the integrity of the optical signal which is an important feature for applications such as radio frequency (RF). The most used optical wavelength for single mode fiber is 1310 nm with higher wavelengths available for distributed sensors or very high bandwidth applications.

III. NETWORK OBJECT ARCHITECTURE

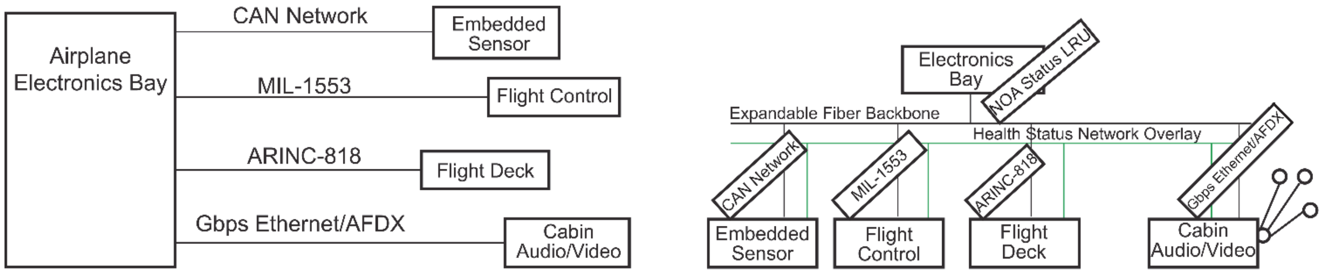
The challenge for designers of new avionics I/O interfaces is how to expand IMA without increasing the cost, complexity, or size of the hardware. Even with the standardization of IMA, these unique connectors, clamps, or interfaces still make it past the watchful eyes of component engineers and end up confounding airplane service centers with long lead times and expensive aftermarket pricing. OEMs such as Boeing, Airbus, Lockheed, and SAAB task installers to service wires in difficult to reach areas. The problems of wiring may start at the design and assembly stage but can carry forward into the field for twenty years or more.

A new architecture could extend the IMA by distributing computing functionality. Processing for example, could be pushed to nodes or objects on a route but do not have to be networked together like ethernet in traditional data/telecom networks. Application specific networks could share their current power rails but additionally have health and status information shared to a network overlay.

The developing ARINC 836 Standard of miniature form factor enclosures, enables a distribution of devices on a fiber optic backbone. The backbone can carry non-critical data, status and health, passively redundant or tapped critical data, or simply power. These enclosures could use the same backplane connectors that were once only found on boards in an IMA cabinet or recent equivalents that are blind-mate and enable a plug and play upgrade. For example, a wi-fi network is an object in the airplane network but it is not centrally managed like an IT network. It is a fixed and closed system from a specific vendor with a service contract. This object does not share a data network with the critical systems in the airplane, but rather reports its status and issues to the airplane network for statistical aggregation. Its operation could be halted or enabled to support the airplane's critical operation. The wi-fi computing hardware starts in an IMA but extends to a NOA of closed, private, and contracted networks serving specific applications.

Another way of looking at avionic networks as objects is shown in Fig. 7.

The embedded sensor network might be a Control Area Network of mechanical items in a galley; the MIL-1553 could be a part of the flight controls; the ARINC 818 network has video going to the cockpit displays from a graphic generator or from a camera in the tail of the airplane; the Audio from the pilot or crew runs over a determined interval on the Ethernet base network via AFDX; all of these are subnetworks that are a part of the overall Avionic



IMA Today **NOA Tomorrow**

Fig. 7 *The new architecture will have separate secure networks but be linked either on a high-speed backbone with protocol or physical barriers; or remain separate where health status control architecture is dropped on top to optimize the airplane's operation.*

network in the airplane. They are networks, but they are also individual objects of the larger airplane network.

IV. CONCLUSION

The need to expand the IMA to include functionality distribution for future NOAs is a result of current demand for new and creative applications which are being driven by increasingly connected aircraft with faster speeds and additional channels. For the airplane manufacturers, NOA provides flexible scalability and a path for adding vendor-developed network products while still maintaining control of these products. Excellent work in industry standards such as the ARINC and SAE committees will continue to support the robust and mature embedded computer board I/O. With fiber optics enabling increased bandwidth, the Network of the Future will have hundreds of lanes, tens of Gbps, and travel at or above Mach speeds.