The Fly-by-Light system for military aircraft

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Abstract: *This paper presents the authors' recent documentary research on the benefits of using the Fly-by-Light system in Military aircraft and the understanding of why Fly-by-Light (FBL) is very promising for the further development of military aircraft. The Fly-by-Light flight system is characterized by the fact that the input control signals from the pilot, motion data, and air data sensors are sent to the flight control computer and from there to the actuators of the control surfaces through a fiber optic cable and the feedback from actuators sensors or other signals is received in the same way, through fiber optic cable connected to the aircraft flight control computer. The first major step in the evolution of flight control systems was the replacement of mechanical flight control systems with a Fly-by-Wire (FBW) flight control system. The next major step is the replacement of Fly-by-Wire (FBW) flight control system with a Fly-by-Light (FBL) flight control system which has some significant advantages such as: reducing the weight of the system, increasing the speed and volume of information transmitted through fiber-optic cable (input and feedback signals), keeping intact the accuracy of the signals along the entire length of the circuit; also, the optical fibers do not present any risk of fire, as they carry only light signals, and the temperature, humidity, and severe weather conditions do not affect the fiber optic cable, which can withstand a pressure of about 0.69 - 1.38 MPa without damaging the cable, unaffected by Electromagnetic Interference (EMI) and the Electromagnetic Pulse (EMP) generated by nuclear blasts. All the advantages listed above provide tactical and safety advantages for the military aircraft and its crew.*

Key Words: *Fly-by-Light (FBL), Fly-by-Wire (FBW), flight control system, Military aircraft, tactical and safety advantages*

1. INTRODUCTION

The structure of a fiber optic cable [4], [7] is presented in Figure 1.

- The fiber **core** is made of very high purity optical glass or special plastic and its thickness (9μm/ 50μm/ 62.5μm), depending on the desired transmission spectrum is less than the thickness of the human hair (about 70μm).
- The **cladding** of an optical fiber has a thickness of 125μm.
- The **coating** of an optical fiber has a thickness of 250μm.
- The **strengthen layer** of an optical fiber has a thickness of 900 μm, which contains a tight buffer wrapped in aramid yarn.
- The **outer jacket** of an optical fiber has a diameter of 1.2mm/ 1.6mm/ 2.0mm/ 3.0mm.

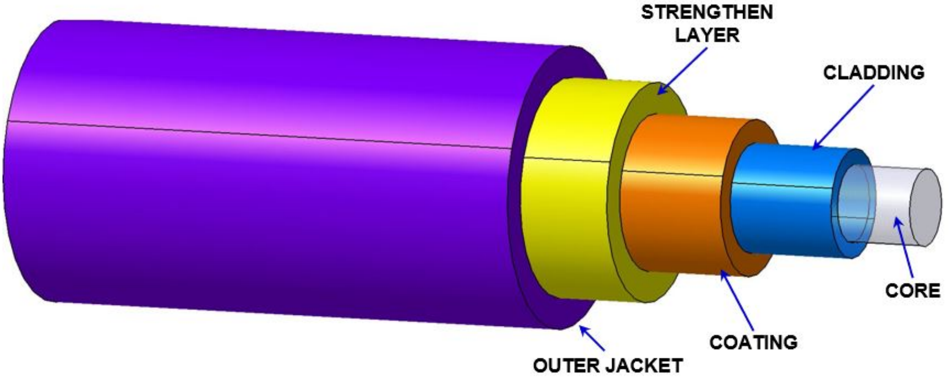

Fig. 1 Fiber optic cable structure

Due to their qualities, fiber-optic cables are extensively used in telecommunications and data networks (Internet).

In recent years, more and more countries and companies have implemented the FBL system for military and commercial aircraft.

2. ADVANTAGES OF USING FIBER-OPTIC CABLES

The fiber-optic cables are used in Fly-by-Light (FBL) Flight Control System of the aircraft, and they replace the copper cables previously used in Fly-by-Wire (FBW) Flight Control System [2], [3], [6].

For this reason, the advantages of using optical fibers are highlighted, as shown in Figure 2 and the following explanations [1], [3], [5].

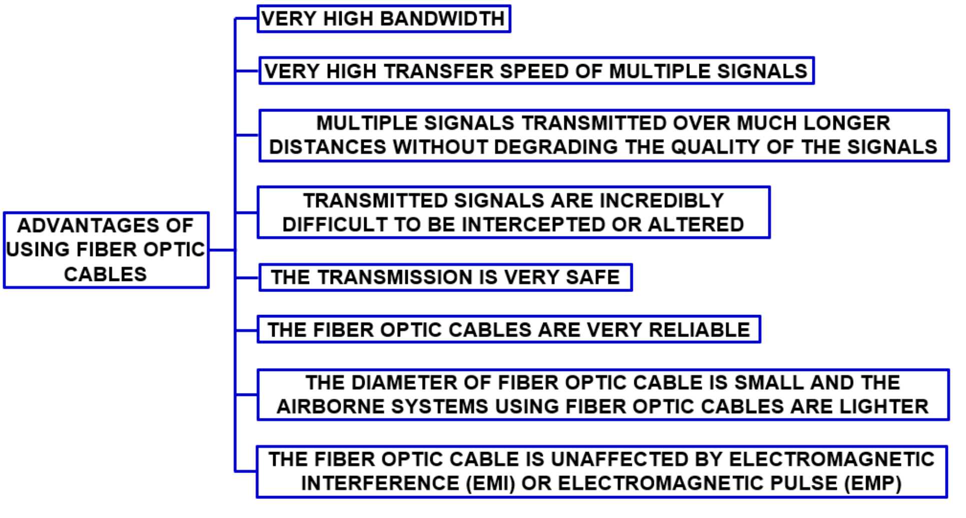

Fig. 2 Advantages of using fiber-optic cables

The fiber-optic cable has a **much higher bandwidth** compared to copper wire, meaning that it can carry multiple signals on one cable instead of a single signal on a copper wire.

The use of fiber-optic cable to replace the copper wire will significantly reduce the weight of the new flight control system (FBL) and therefore it will reduce the weight of the entire aircraft.

Fiber-optic cables are characterized by the **very high transfer speed of multiple signals**, with the speed of light through the glass, while the copper wire can carry a single signal at a much lower speed, namely the speed of electric current through the copper wire.

Multiple light signals can be carried by the fiber-optic cable over much **longer distances,** without degrading the quality of the multiple light signals, since the signal sent through the optical fiber is much less likely to be altered during transmission, compared to the copper wire.

The core of fiber optic cables is made of glass, which makes it **incredibly difficult to intercept** the signal without sectioning the cable, even in the case of very qualified people. This makes transmission through fiber-optic cables **very safe**, compared to the copper wire which can be intercepted very easily, even by less qualified people.

The fiber-optic cables are **very reliable** because they only transmit light signals, without the risk of fire, while the copper wires heat up when transmitting electrical signals and, in addition, the transmitted electrical signal can be altered by environmental conditions (severe weather conditions such as lightning, elevated temperature, high humidity, etc.).

The diameter of fiber optic cable **is smaller** than the copper wire, because the fiber-optic cable allows the transmission of multiple signals without affecting the speed or quality of the signals, while the transmission of the electrical signal through the copper wire is strictly dependent on the size of the wire.

Consequently, the weight of a flight control system using fiber-optic cables (FBL) is significantly reduced compared to the FBW system.

The fiber-optic cables do not heat up because they transmit only light signals (photons).

The fiber-optic cable is **unaffected by electromagnetic interference (EMI) or electromagnetic pulse (EMP)** generated by nuclear detonation and therefore does not need protective shielding like the copper wire (which can be affected by its electromagnetic field, by the electromagnetic frequency given by military electronic jamming devices, other existing electronic devices in the aircraft or even lightning).

3. FLY-BY-LIGHT IN MILITARY AIRCRAFT

The Fly-by-Light (FBL) system installed on military aircraft, using fiber-optic cables, has multiple advantages highlighted above, which provide tactical and safety advantages for the military aircraft and its crew.

The architecture of the Fly-by-Light (FBL) Flight Control System is presented in Figure 3 and it is similar to the structure of an FBW system, but the significant differences between the two systems (FBL and FBW) [1], [3], [5] will be presented further.

• The fiber-optic cable is replacing the copper wires.

• The fiber-optic cable does not heat up because it transmits only light signals (photons).

• The fiber-optic cable has a high bandwidth, so the number of cables is reduced, and the weight of the Flight Control System is also reduced.

• The fiber-optic cable is unaffected by electromagnetic interference (EMI) so the cables can be positioned near electronic devices, near weapons, or even near fuel tanks into the aircraft.

• The fiber-optic cable is unaffected by electromagnetic pulse (EMP) generated by nuclear detonation and the FBL system recovers in a few minutes after explosions that generated strong radiation so the aircraft can be used in the war zone if the mentioned explosions did not hit the aircraft directly.

• The flight control computer has a high capacity, and it is built with open architecture for both components: hardware and software, so that it can be easily adapted depending on the tactical situation, the type and quantity of weapons loaded, type of missions, etc.

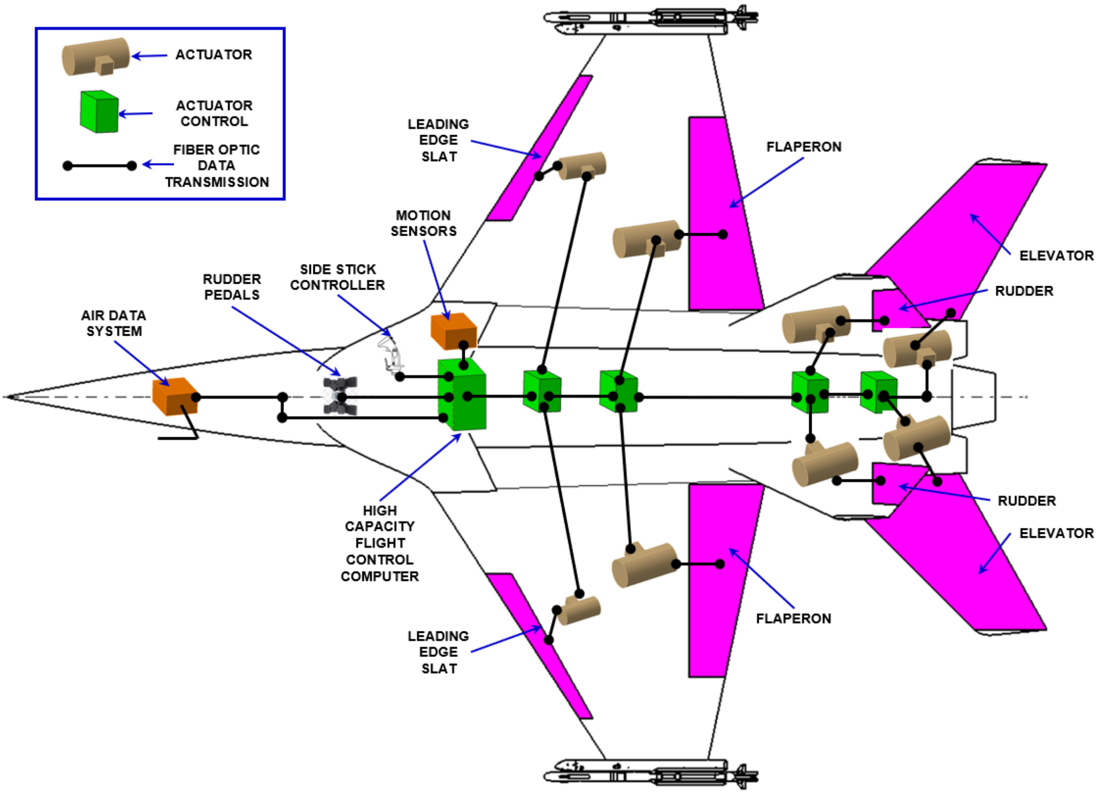

Fig. 3 The Fly-by-Light (FBL) Flight Control System

• The position sensors of the maneuverable surfaces are replaced with optical sensors.

• The used actuators can be Electro-Mechanical Actuator (EMA), but the actuator controller must be of optical type.

4. AIRCRAFT USING THE FLY-BY-LIGHT (FBL) SYSTEM

The A-7D test aircraft, equipped with the complete Fly-by-Light (FBL) Flight Control System flew first on 07.02.1975 and then on 24.03.1982, in California, US [3].

The Kawasaki XP-1, a Japanese maritime reconnaissance aircraft, had its first flight in September 2007, and it has the distinction of being the first operational aircraft in the world using a Fly-by-Light (FBL) Flight Control System [8].

On 18.03.2018 Gulfstream demonstrates the Fly-By-Light Aircraft Control System, during a nearly 75-minute flight [2].

China intends to use the Fly-by-Light (FBL) Flight Control System for the sixth-generation fighters [6].

India is developing research to use the Fly-by-Light (FBL) Flight Control System for the sixth-generation fighters for AMCA. The Advanced Medium Combat Aircraft (AMCA) is an Indian program to develop fifth to sixth-generation fighter aircraft for the Indian Air Force and the Indian Navy [9].

Many companies such as Boeing and Airbus are interested in implementing the Fly-by-Light (FBL) Flight Control System on new aircraft or, if they have the opportunity when modernizing existing aircraft.

5. CONCLUSIONS

The technology using fiber-optic cables are extensively used in telecommunications and data networks. Recently, the glass has been replaced with special transparent plastic which helps for a significant reduction in weight. Due to its major advantages, the Fly-by-Light (FBL) Flight Control System is increasingly used in commercial aircraft, but especially in military aircraft.

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