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Luft- und Raumfahrt - Faseroptische Systemtechnik - Handbuch - Teil 003: Verfahren zur Fertigung und Installation von Leitungsbündeln

Série aérospatiale - Systèmes des fibres optiques - Manuel d'utilisation - Partie 003 : Règles de l'art pour la fabrication et l'installation des harnais

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EUROPEAN COMMITTEE FOR STANDARDIZATION
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Management Centre: rue de Stassart, 36 B-1050 Brussels

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Foreword

This European Standard (EN 4533-003:2006) has been prepared by the European Association of Aerospace Manufacturers - Standardization (AECMA-STAN).

After enquiries and votes carried out in accordance with the rules of this Association, this Standard has received the approval of the National Associations and the Official Services of the member countries of AECMA, prior to its presentation to CEN.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by January 2007, and conflicting national standards shall be withdrawn at the latest by January 2007.

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Introduction

a) The handbook

The handbook draws on the work of the Fibre-Optic Harness Study, part sponsored by the United Kingdom's Department of Trade and Industry, plus other relevant sources. It aims to provide general guidance for experts and non-experts alike in the area of designing, installing, and supporting multi-mode fibre-optic systems on aircraft. Where appropriate more detailed sources of information are referenced throughout the text.

It is arranged in 4 parts, which reflect key aspects of an optical harness life cycle, namely:

- Part 001: *Termination methods and tools*
- Part 002: *Test and measurement*
- Part 003: *Looming and installation practices*
- Part 004: *Repair, maintenance and inspection*

b) Background

It is widely accepted in the aerospace industry that photonic technology offers a number of significant advantages over conventional electrical hardware. These include massive signal bandwidth capacity, electrical safety, and immunity of passive fibre-optic components to the problems associated with electromagnetic interference (EMI). To date, the latter has been the critical driver for airborne fibre-optic communications systems because of the growing use of non-metallic aerostructures. However, future avionic requirements are driving bandwidth specifications from 10's of Mbits/s into the multi-Gbits/s regime in some cases, i.e. beyond the limits of electrical interconnect technology. The properties of photonic technology can potentially be exploited to advantage in many avionic applications, such as video/sensor multiplexing, flight control signalling, electronic warfare, and entertainment systems, as well as in sensing many of the physical phenomena on-board aircraft.

The basic optical interconnect fabric or `optical harness' is the key enabler for the successful introduction of optical technology onto commercial and military aircraft. Compared to the mature telecommunications applications, an aircraft fibre-optic system needs to operate in a hostile environment (e.g. temperature extremes, humidity, vibrations, and contamination) and accommodate additional physical restrictions imposed by the airframe (e.g. harness attachments, tight bend radii requirements, and bulkhead connections). Until recently, optical harnessing technology and associated practices were insufficiently developed to be applied without large safety margins. In addition, the international standards did not adequately cover many aspects of the life cycle. The lack of accepted standards thus lead to airframe specific hardware and support. These factors collectively carried a significant cost penalty (procurement and through-life costs), that often made an optical harness less competitive than an electrical equivalent.

c) The fibre-optic harness study

The Fibre-Optic Harness Study concentrated on developing techniques, guidelines, and standards associated with the through-life support of current generation fibre-optic harnesses applied in civil and military airframes (fixed and rotary wing). Some aspects of optical system design were also investigated. This programme has been largely successful. Guidelines and standards based primarily on harness study work are beginning to emerge through a number of standards bodies. Because of the aspects covered in the handbook, European prime contractors are in a much better position to utilise and support available fibre optic technology.

1 Scope

Looming and installation practices are a critical aspect of any aircraft electrical/avionics installation. In order to provide a reliable and efficient system it is important that the harness installation is designed for reliability and maintainability. This concept holds true for both copper based and fibre optic harnesses.

The objective of this part of EN 4533 is to provide technical advice and assistance to designers and engineers on the incorporation of fibre optic harnesses into an airframe, while maintaining maximum compliance with current aircraft electrical harness procedures. This part considers the looming and installation aspects during initial design, throughout the manufacture and installation of the fibre optic harness and how the practices chosen affect through life support of the harness.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

EN 4533-001, *Aerospace series — Fibre optic systems — Handbook — Part 001: Termination methods and tools.*

3 Initial design considerations

3.1 General

The installation of fibre optic harnesses should aim to mirror that of copper systems and comply as much as possible with current general aircraft electrical harness procedures. There are numerous installation specifications detailing the requirements for the routing of copper based harnesses, however they are very similar in content, therefore fibre optic harness routing will have to fulfil the following criteria:

a) Accessibility for inspection and maintenance;

b) Prevent or minimise the risk of damage from:

- Chafing, scraping or abrasion;
- Use as handholds or as support for personal equipment;
- Damage by personnel moving within the aircraft;
- Stowage or movement of cargo;
- Battery electrolytes and fumes;
- Stones, ice, mud and burst tyre debris in landing gear bays;
- Combat damage (to the maximum extent practicable);
- Loose or moving parts;
- Moisture and fluids;
- Localised high temperatures;
- Frequent mating and de-mating of connectors;
- Exposure to high temperature/high vibration areas.

Copper installations are prone to electrical interference and their use is restricted in “volatile” zones. Fibre optic cables are virtually immune to electrical interference and are ideally suited for use in, or routing through “volatile” zones. Examples of areas that fibre optic harnesses may provide a better solution over copper include:

c) Areas where there are high levels of electrical, field strength;

d) Areas where electric fields need to be kept to a minimum, e.g. compass deviation;

e) Routing through and close to fuel tanks;

f) Close proximity to Electrically Initiated Explosive Devices (EIEDs) and their systems.

During the design phase of a fibre optic installation routing considerations need to be addressed when determining the optimum routing, these include:

g) System criticality;

h) Harness accessibility, improves on-aircraft repair and maintenance, but should not degrade system protection;

i) System segregation and redundancy, maximisation of damage limitation;

j) Accessibility of connectors;

k) System and component repair and maintenance issues;

l) Introduction of dormant fibre in harnesses and/or extra fibre lengths may reduce on-aircraft repair times.

3.2 System design considerations

3.2.1 Connectorisation and available power budget

Careful attention should be made to the number and placement of connectors in the optical harness. The final choice and location of connectors needs to consider the required performance, reliability and maintenance aspects of the system. These aspects often conflict with each other in system design and so some trade-off should be performed at the design stage.

Of primary importance is that the harness components do not introduce a loss that exceeds the power budget of the system. Provided that sufficient power budget is available, the use of appropriately positioned connector breaks can improve the maintainability of the system. For example, in areas of high maintenance activity where there is an increased likelihood of damage, the use of additional connector breaks will facilitate a quick and simple replacement of damaged cable. This in turn has to be traded off against the possibility that the additional connectors may themselves fail, reducing the reliability of the system. Experience has shown that failures at or near to the connector are not an uncommon failure mode, particularly where loads placed on the harness are easily transferred to the connector backshell. Careful placement of the connector and the use of appropriate harness tie-down mechanisms will reduce the likelihood of this type of failure.

In summary the introduction of additional connectors should be considered if the loss increase induced by the introduction is within the power budget of the system, and the additional connectors improve maintainability without causing impact on the reliability of the system.

3.2.2 The use of redundancy

Redundancy can be utilised in a fibre optic application without excessively diminishing the weight savings attained by using fibre optic cable. However, the introduction of additional cables will inevitably increase initial cost and system complexity, together with the additional problems of cable end/ferrule protection and stowage. In addition, any spare or redundant fibres would be subject to the same or similar environmental conditions as the 'live' fibre it is duplicating.

Clearly, the more in-built redundancy the increased survivability of the system. Deciding on the level of redundancy and depth required, should be based on a number of factors, these include:

- **Criticality**
  How important is the system to the operation of the aircraft? This may mandate that 2 (duplex) or 3 (triplex) levels of system redundancy are required for highly critical systems such as flight controls. In this case all paths are fully connected as part of the system to allow the system to function even if a failure occurred.

- **Complexity/Maintainability**
  The introduction of additional 'spare' fibre would inevitably increase the complexity of system design, which in turn would directly affect the weight and space envelope factors, cost, and to a lesser degree, the maintainability of the system.

- **Weight and space envelope**
  Careful consideration would have to be taken into account during the design phase to ascertain the depth of redundancy required against weight and space envelope restrictions and limitations.

- **Repair**
  Repair of systems can be improved with the incorporation of redundancy and/or dormant fibre, depending on the system damage sustained. The ability to transpose damaged fibres with 'spare' fibres, negating the need to remove and replace harnesses may prove beneficial, however, the question raised is 'how many spare fibres do you include in each harness?

The time taken to replace the damaged fibre should also be recognised as an important issue, especially in a commercial application where aircraft down time needs to be kept to a minimum. Therefore it may be easier, and quicker to remove a complete harness assembly (complete with connectors) and replace with a pre-assembled unit.

3.2.3 Spare cabling

Inclusion of additional spare/redundant fibres is probably the easiest method to improve the survivability or maintainability of any airborne fibre optic installation. It provides a system capability that will allow continued operation even if damage has been sustained, or a failure to an element of that system has occurred.

Current copper systems do not incorporate dedicated spare cables or dedicated lines of redundancy. However, they include elements of back up in their design [secondary systems, Line Replacement Items (LRI), etc].

3.2.4 Dormant fibres

Redundancy also encompasses ‘dormant’ fibre in harnesses. The use of dormant fibres would allow replacement of damaged fibres within a harness without the need for removal of the harness or introduction of new fibre into the harness. However, including dormant fibres within a harness would also introduce a number of technical problems, including:

- Un-terminated fibre would require end protection to prevent contamination (including fluid wicking).

- Un-terminated fibre would require termination 'on-aircraft' when required for use.

- Pre-terminated single way connector ferrules require safe stowage to prevent damage/contamination of the end face.
- Pre-terminated ferrules of multi-way connectors, stored in spare receptacles require the dismantling of connectors at each end of the affected harness, removal from the connectors of the faulty and spare fibre contacts and transposition of the contacts to their relevant receptacles and re-assembly of the connectors.
- Possible weight penalties depending on number of fibres/contacts/connectors required.
- Damage to a harness could extend into the dormant fibre rendering it unusable.

A reduction in the number of listed problems could be achieved, such as routing spare fibre external to, and away from the original harness, weight penalties may be minimal due to the overall weight savings of fibre optic installations over copper installations.

Further constraints including the limitation of operational maintenance facilities, length of repair time and limitations of available tooling may make the use of dormant fibres untenable. Therefore the advantages/disadvantages for the introduction of dormant fibres in a system needs to be carefully considered during the design phase.

3.3 Harness routing considerations

3.3.1 General

Studies within the Harness Study have shown avionic fibre cables to be very tolerant of conventional electrical looming and installation methods and indeed, routing fibre optic harnesses along/within existing copper looms/harnesses is, in many cases, advantageous. The hybrid harness will provide additional mechanical support and strain relief, without the need for specialized, additional clamping or routing requirements. In general terms it is considered that sufficiently ruggedised 'avionic' cables can be routed using exactly the same design criteria as electrical cables.

3.3.2 Drip loops

Drip loops are incorporated where there is a probability that fluids will affect a harness or system component. The harness or cable should be routed in such a manner that the fluid cannot migrate along the harness or cable into the rear of the connector (see Figure 1).

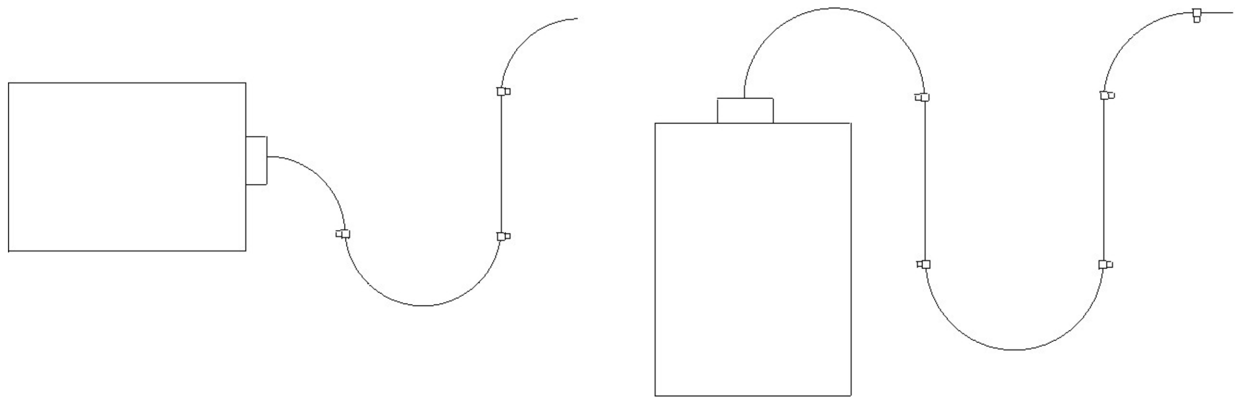

Figure 1 — Typical types of drip loop

When installing fibre optic harnesses careful consideration needs to be taken into account when introducing drip loops. The fibre should not exceed the long term minimum bend radius, therefore, if routing along existing copper looms with a smaller minimum long-term bend radius it may be necessary to adjust the copper installation to allow for the fibre bend radius, or route the fibre harness separate to the copper loom and introduce another drip loop.

3.3.3 Circular paths

With the introduction of system segregation and separate routing the problem arises of multiple fibre optic cables routed from varying locations terminating into a single-point multi-way connector.

During the design stage it is important that the routing of fibre optic harnesses takes into account the accessibility of routing terminated/connectorised fibres through the airframe structure, to prevent the requirement for end termination in the airframe.

3.4 Securing and attachment mechanisms

As with any harness installation, methods of cable support and retention are important factors in order to guide and retain the harness, while at the same time limiting the effects of stress on the cables.

The use of dedicated, special-to-type fibre optic harness routing and clamping methods maintain controlled conditions on the fibres. However these methods encroach on the airframe space envelope while increasing weight and cost. Providing the performance of the fibre optic cable is not compromised, it is recommended that cables be routed in the same way as existing electrical cables. Work was performed as part of the Fibre Optic Harness Study into how conventional methods of attaching and retaining electrical cable harnesses may affect the performance of the cable and ultimately the transmission of light. It was felt that if current electrical support and retention techniques could be applied this would make the introduction of the technology much more acceptable to the installer by reducing training and installation costs. Many of the results highlighted that far from being a special case, the fibre-optic cable types tested exhibited a performance that allowed existing retention and support methods to be used that could not be applied to high bandwidth electrical cables, such as co-axial cables.

The current methods of cable support and retention used on airborne applications harnesses include:

- Cable ties;
- Lacing cord;
- Raceway harpoons;
- ‘P’ clips;
- Raceway clamps;
- Bobbins.

The effects of these retention devices on multi-fibre open harnesses and raceways and associated temperature variation effects were investigated. The results obtained indicated that the losses introduced by the retention methods on current generation avionic fibre optic cables were minimal.