SPECTRUM CONTROL

WHITE PAPER

WHY FIBRE OPTIC SOLUTIONS ARE THE RIGHT CHOICE FOR DEFENSE AVIONICS

Fibre optic solutions are proven to have the reliability and robustness required in defense avionics systems. They also offer many important advantages over copper-based solutions and should be the first choice when deploying new defense avionics systems and when replacing legacy avionics systems.

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Executive Summary

Using fibre optics for defense avionics systems isn't a new approach. The Eurofighter Typhoon and the F-35 Joint Strike Fighter have successfully leveraged a fibre optic communications backbone for key systems — flight, radar, weapons detection, weapons launch, and countermeasures — for many years. The sixth-generation jet fighter, Tempest, will continue the trend, and may also extend fibre optics to other areas of the aircraft.

Fighter jet developers choose fibre optics because they know it's the only communications technology that can efficiently and cost effectively transport the massive volumes of data needed today. fibre optic solutions are essential to accelerate response times for time-sensitive applications, such as radar, and support advanced, data-intensive applications, such as fly-by-wire (fly-be-light).

The decision to use fibre optics in defense avionics goes beyond fighter jets. For example, fibre optics are used for surveillance systems in helicopters. In this case, fibre's light weight is important because helicopters have less powerful engines than airplanes. In rockets and satellites, fibre optics is ideal because it combines very high speeds with the extreme resiliency needed in space.

Fbre Optics Is the Only Viable Option for Modern Defense Applications

When you consider the rapid pace of evolution in defense avionics systems, it's clear that fibre's time has arrived: The Eurofighter Typhoon transports data at 20 Mbps, while the F-35 Joint Strike Fighter transports data at 2.5 Gbps. Media reports say the Tempest is being designed around a radar system that can collect 10,000 times more data than earlier radar systems and analyze it onboard the aircraft. The system will be able to record as much data as the internet traffic of Edinburgh, Scotland, every second.[1]

Applications that need network speeds of 100 Gbps and higher can only be supported in a practical way with fibre optics. Even if the aircraft doesn't yet include advanced applications, the bandwidth-distance products used to connect backplanes, line cards, and chip components already require optical interconnects that can support speeds from 100 Gbps to 3 Tbps.

Based on these requirements, every defense aircraft should be implementing fibre optics.

[1] The U.K.'s New Fighter Jet Has a Radar System That's Just Ridiculous. Popular Mechanics, October 2020.

Misconceptions Stop Aircraft Designers From Taking Advantage of Fibre Optics

Although fibre optics are already bringing reliable, high-speed communications to fighter jets, helicopters, and space vehicles, some aircraft developers and avionics systems integrators continue to rely on heavier, costlier, and slower copper-based solutions. Unfortunately, their choice is usually due to misconceptions about fibre's ability to meet defense requirements.

Fibre Optics Are Far More Robust and Resilient Than People Realize

Many people who have not worked with fibre optics still think the physical fibres are fragile. The misconception may be because fibre optics are made of glass, which we typically know to be inflexible and easily broken.

However, fibre optics are produced in a very different way than the glass items we use in our everyday lives. fibre optics are manufactured using a specialized, high-temperature process and ultra-pure elements that result in a very thin but extremely strong and flexible fibre. The fibres in a modern fibre optic cable have a bend radius of 7 mm, which means they can be looped and curved for easy installation in cramped aircraft environments, with no worries about breakage.

Fibre optics for defense applications are also thoroughly protected with multiple layers of protective materials to provide additional resilience. Two layers of flexible plastic coating sheathe the fibres. Then a layer of polyamide fabric is added, followed by a layer of lightweight yet highly protective weave, such as that used in bulletproof vests. Finally, the combined layers are encased in a robust plastic shield that protects against cutting and crushing (Figure 1).

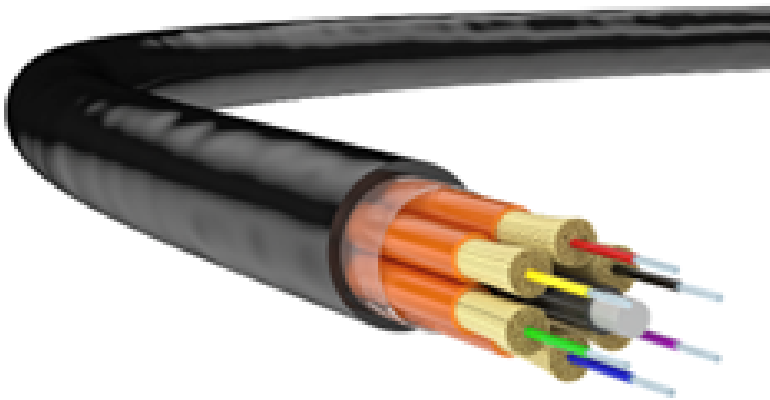


Figure 1. Layers of fibre Optic Protection

Fibre Optics Meet MIL Standards

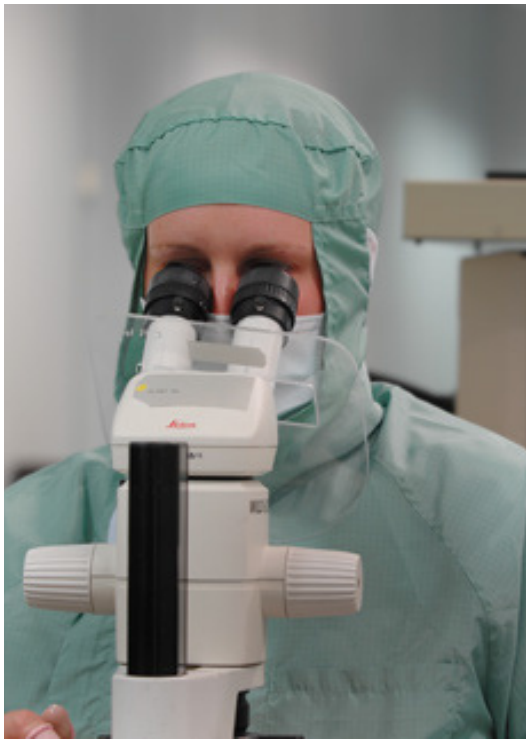
The reliability of fibre optics is also questioned. But fibre optic solutions for defense comply with key MIL specification standards, including MIL-PRF-38534, which ensures they can reliably perform as expected, despite the extreme vibrations and temperature ranges that occur on defense aircraft.

The most robust and reliable fibre optic solutions comply with MIL-PRF-38534 Class K, which ensures they meet the extremely stringent reliability and resilience levels required by tier one space contractors. With Class K certification, fibre optic solutions are fully certified and qualified with standards related to inspection flow, screening flow, conformance inspection, and periodic inspection flow, among other conformance process inspection items. They're also certified to reliably operate across temperatures ranging from -55°C to+125°C.

It's worth noting that there have not been any failures in the optical systems installed in the Eurofighter Typhoon, and those systems started production in 1999.

Fibre Optic Expertise Abounds in the Industry

While there may have been a lack of fibre optic expertise in the early days of the technology, we're now well beyond that point. Today, there are numerous organizations with deep fibre optic knowledge and specialized expertise in fibre optic deployments for defense avionics applications, and they've invested in developing fibre optic training programs.



These organizations have the resources to efficiently train in-house mechanics and technicians in the proper techniques for fibre optic handling and routing, interconnects, connector inspection, and polishing. When existing staff can readily develop the skills required for fibre optic handling and maintenance, there's no need to search for and hire new aircraft mechanics and technicians, and aircraft get back in the air sooner.

Fibre Optics Outperform Copper in Every Way

A point-by-point comparison across the physical and logical aspects of fibre optic and copper performance makes it clear that copper-based communications solutions are no longer the right choice for defense avionics systems.

Lower Weight, Less Space

Fibre optic cables are much lighter than copper cables and can transport far higher data volumes using fewer cables. Optoelectronic solutions are also much smaller than electrical solutions. With the weight and space savings fibre optics enable, defense aircraft can increase payload and maneuverability while reducing fuel consumption. A direct comparison highlights fibre's considerable advantages (Table 1).

Table 1. Weight and Space Comparison Between Copper and fibre Optics

Comparison	Copper	Fibre	Fibre Savings
Weight	1 meter of quadrax cable: 40 g	1 meter of optical fibre with 1.8 mm protective jacket: 4 g	90%
Space	Single-channel electronic solution: 60 mm x 15 mm x 15 mm	4-channel optical solution: 25 mm x 25 mm x 5 mm	77%

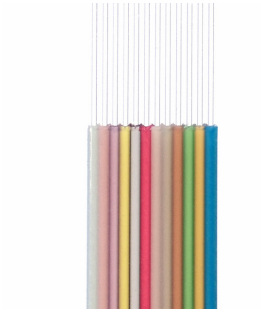
When the differences between the two options are considered in the context of a modern, high-speed defense application, the stark contrast between the two options is further apparent (Figure 2).

Figure 2. fibre Ribbon Cable Versus Copper Cable Bundle for a 1 Tbps Application

Copper

- Each of 36 matched cable pairs: 3mm diameter
- Cable harness for a bank of 12 channels: 40mm x 5mm
- Total shielded connecter footprint: 20mm x 6mm

Fibre



- Each of 36 matched cable pairs: 0.25mm diameter
- Cable harness for a bank of 12 channels: 3mm x 0.3mm
- Single optical connecter footprint: 12 mm 20mm x 6mm

Higher Data Speeds and Capacity

Fibre is the only communications technology that combines the speed, capacity, and low latency required to meet the advanced and real-time application requirements on modern defense aircraft.

Fibre optics can efficiently deliver Tbps speeds, whereas copper is not typically a feasible option for avionics applications that require speeds higher than 100 Gbps. Overall, optical fibre can carry up to 10 times more data in a single core than copper wires.

Better Signal Security and Integrity, Lower Power Consumption

Fibre optic cables are extremely difficult to physically hack into. In contrast, it’s relatively easy to break the seal on copper cables and listen in. Crosstalk between the copper wires in a bundle increases the risks associated with physical intrusion. If this type of physical intrusion was attempted on a fibre optic cable, the fibre would very likely break. And there’s no crosstalk between adjacent links in fibre optics so signals cannot be unintentionally exposed.

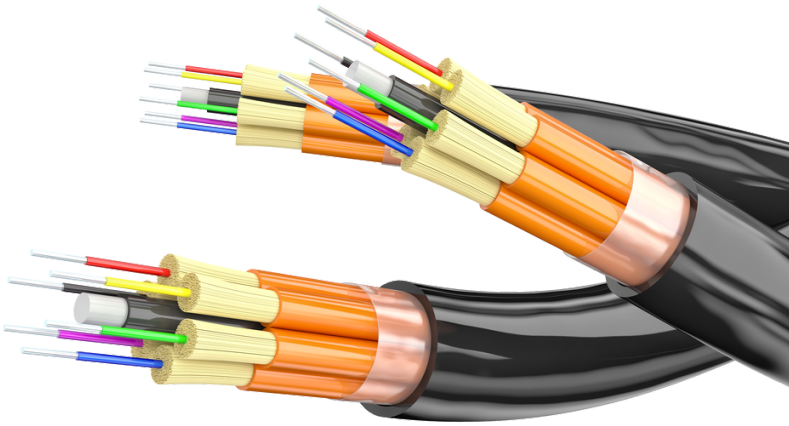
fibre also has much lower attenuation over distance than copper, which means it delivers higher signal integrity (Table 2).

Copper Deployment	Copper Loss	Fibre Deployment	Fibre Loss
Backplane - standard materials • Speed: 10 Gbps • Frequency: 5 GHz • Distance: 0.8 m	20 dB	Multimode 850 nm OM3 optical fibre • 10 Gbps • 40 Gbps • 100 Gbps • Distance: 500 m	< 3 dB
Backplane - improved materials • Speed: 50 Gbps • Frequency: 2.5 GHz • Distance: 0.8 m		Multimode 850 nm OM4 optical fibre • 10 Gbps • 100 Gbps • Distance: 500 m	
Low-loss dielectric coax cable • Speed: 40 Gbps • Frequency: 20 GHz • Distance: 0.8 m			

To compensate for the signal losses over distance with copper cables, repeater amplifiers must be added at regular intervals to strengthen the signal, further increasing weight, space, and cost requirements. This is not the case for fibre, which offers unrepeated link distances that are orders of magnitude higher than copper:

- Copper: 100 m unrepeated link distance
- Multimode fibre: 4.5 km unrepeated link distance
- Single-mode fibre: 40 km unrepeated link distance

Because fibre doesn't need repeater amplifiers to boost output signals as copper does, fibre optic solutions consume very little power. For example, a fibre optic solution that can transport data at 40 Gbps uses less than 1 W of power.



Safe Installation Anywhere in the Aircraft

Fibre is intrinsically safer than cooper because it doesn't generate electromagnetic compatibility (EMC) emissions and it's not sensitive to EMC emissions from other systems. Copper both generates EMC and is sensitive to emissions from other systems, a significant issue in defense aircraft that are packed with electronics.

To provide adequate radio frequency (RF) shielding, copper cables must be wrapped in layers of plastic and foil, then in a separate metallic jacket, which adds to the weight and space these solutions already consume. Copper also requires specialized metallic connectors to protect against EMC issues.

With its flexibility and complete lack of EMC issues, fibre can be easily and safely routed throughout aircraft with no worries about the potential for explosions or fires. Even when copper cables are thoroughly wrapped and shielded to protect against EMC incompatibilities, there are still many areas of aircraft, such as fuel tanks, where they cannot be safely installed.

As we will explore in more detail in the next section, this limitation restricts the potential for defense organizations to fully leverage advanced applications that will help them improve mission effectiveness, increase operational efficiency, and prevent mechanical and electrical failures on the aircraft.

Lower Total Cost of Ownership

Fibre optics are slightly more expensive to purchase than copper. However, when the full costs of fibre, including interconnects, routing, and cost-per-meter of fully shielded cabling are compared to the same costs for copper, fibre is the less expensive option. fibre's ease of installation and lower power consumption further reduce total cost of ownership compared to copper.

Fibre Optics Take Defense Avionics to the Future

Together, fibre's many advantages over copper open the door to applications that improve defense capabilities ranging from situational awareness and weapons detection to aircraft monitoring, and preventive maintenance. Here are just a few examples of defense avionics applications where fibre optic's unique benefits create new opportunities and reduce risks:

- **Radar systems**, where instant access to accurate and complete mission-critical radar data is essential for accurate situational awareness and effective responses. fibre's speed and signal integrity significantly minimize the risk that mission-critical radar data will be slow, unreliable, or incomplete.

- **Missile-detection and counter-measure systems**, where infrared technologies and artificial intelligence (AI) are used to quickly and accurately detect the infrared signature of missiles and notify pilots so they can initiate or approve the appropriate response. Again, fibre's speed and signal integrity are essential.

- **Reconnaissance video surveillance systems and vision systems**, where high-speed, high-definition (HD) images are used for take-off and landing. With fibre optics, HD cameras can be installed anywhere on the aircraft, including wingtips, to provide the precise visuals aircraft systems and pilots need to make the right decisions.

- **Preventive maintenance applications**, where fibre optics throughout the fuselage monitor stress, strain, and temperature levels while the plane is in the air so parts performance and fatigue can be accurately measured as the stresses are applied for earlier detection. For example, the light reflection from a sapphire crystal can be used to measure the temperature of the flame within a jet engine to ensure it is firing in an optimal way. Without this capability, the aircraft must be x-rayed on the ground, which takes more time, and only detects issues after they become visible.

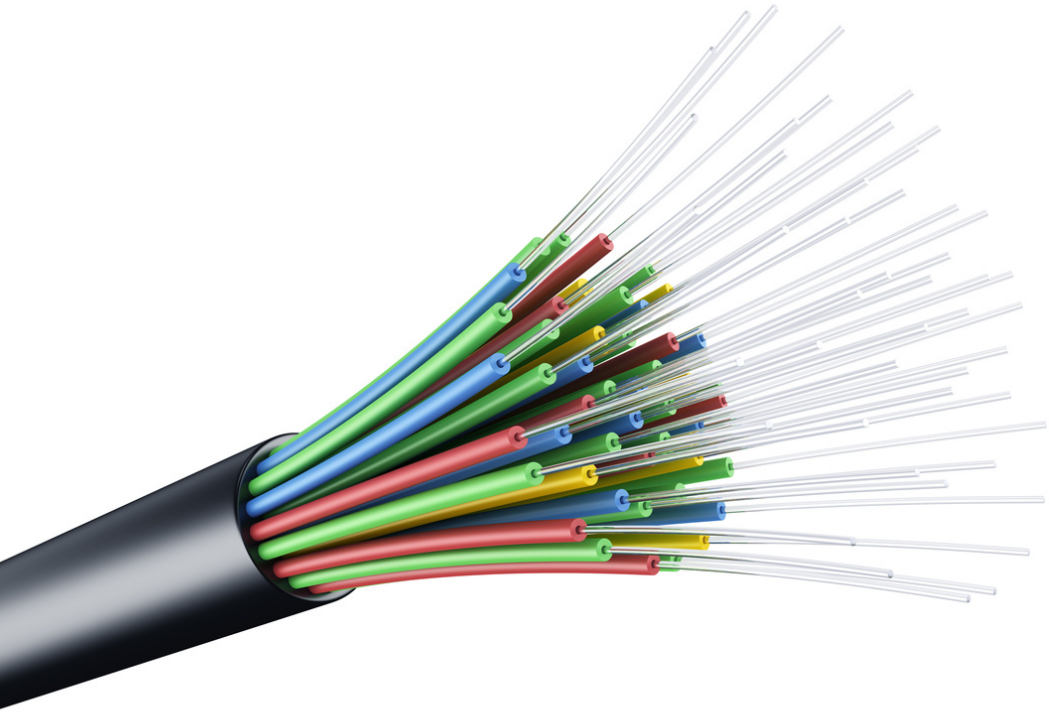
- **Fuel monitoring and refueling applications**, light reflection and speed are used to measure fuel levels in aircraft. Only fibre optics provides the light reflection characteristics required for this application and is safe enough to be routed through fuel tanks. fibre optics can also be used in refueling tankers to ensure there is no delay in boom movements that could put in-flight refueling operations at risk or scratch the anti-radar paint on fighter jets.

Fibre Optic Solutions for Any Program, Platform, and Application Requirements

Fibre optic solutions that meet defense organization requirements are available today. Each solution is designed and packaged for the specific applications and environments on defense aircraft to ensure they provide the optimal size, weight, power, and cost (SWaP-C).

The most advanced fibre optic solution vendors offer convenient, off-the-shelf solutions that target common defense avionics performance and reliability requirements and deployment scenarios. They also have the expertise and agility to fully customize their fibre optic solutions to meet even the most unique and challenging requirements. These vendors can tailor every aspect of their fibre optic solutions, including the:

- Numbers of fibres in the cable
- Lengths of fibres
- Routing path for fibres
- Connectors and terminations used
- Board design and manufacturing process
- Packaging materials



Spectrum Control is a Leader in Fibre Optic Solutions for Defence Avionics and Space Applications

Spectrum Control has been designing and manufacturing high-reliability, high-temperature electronic components, modules, and subsystems for more than seven decades, and has 30 years of experience developing solutions for defense avionics and aerospace applications.

Based on our deep expertise in the optoelectronics and microelectronics industries, we've been selected to supply fully customized fibre optic solutions for numerous defense avionics programs, including the high-profile Eurofighter Typhoon and F-35 Joint Strike Fighter. And we are a partner of choice for all hybrid circuits for a leading European defense and space manufacturer.

Our solutions are selected for their robust reliability, including their ability to meet the rigors of space flight. More than 50,000 of our fibre optic front-end transceivers are in service, including many that have been operating in optical data buses since 2000.

Fully Certified fibre Optic Solutions

We specialize in off-the-shelf and fully customized integrated fibre optic solutions, systems, and subsystems, and are very experienced in extremely harsh environment applications where the smallest possible footprint is required.

Our OPTO-FIRE™ portfolio includes a range of radiation-tolerant, multimode fibre optic transceivers that feature ultra-low power consumption, are verified to provide stable performance from -50°C to +100°C, and are available with hermetic packaging. All of our offerings and our operations meet key defense performance and international quality standards, including:

- MIL-PRF-38534 Class K for the highest reliability levels required in space applications
- MIL-PRF-38534 Class H for military quality levels
- AS9100D for quality management systems in aerospace
- ISO 9001:2008 for quality management systems

Our accreditations include:

- ISO/IEC 17025 for testing and calibration laboratories
- International Electrotechnical Commission Quality Assessment System for Electronic Components (IECQ)
- MIL-STD-883 for testing microelectronic devices for use within military and aerospace electronic systems
- MIL-STD-202 for testing electronic and electrical component parts

Our dedication to developing fibre optic solutions that meet the highest standards ensure our offerings outperform rugged and commercial-off-the-shelf (COTS) fibre optic solutions in terms of data rates, operational temperature ranges, performance stability over temperature ranges, packaging ruggedization, and manufacturing quality.

Learn More

To learn how Spectrum Control can meet your unique and challenging requirements for fibre optics in defense avionics, visit our website or contact us.

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