Considerations When Selecting MIL-STD-1553B Components

By MilesTek

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Introduction

The interconnected backbone of a MIL-STD-1553B vehicle depends on the electrical and mechanical reliability of the components, the design, and the installation. With the vast array of MIL-STD-1553B specified sub-assemblies, there are factors that can go overlooked for passive components such as couplers, cables, and connectors. Often built with kilometers of wiring, aircraft in particular can be difficult to troubleshoot and must be inspected frequently for potential failures such as intermittent connections, shorts, and corrosion. Still, these passive components that make up the network can be individually assessed to operate with a high level of integrity.

Bus Couplers Considerations

MIL-STD-1553B specifies that data bus coupler must be placed between the main data bus and the vehicle subsystems, computer system, or terminal in order to protect the integrity of the entire network. The data bus coupler is often called a ‘stub coupler’ where a ‘stub’ is simply a pair of wires connecting avionics components to the main bus. MIL-STD-1553B and STANAG 3838 further specifies that each stub coupler come equipped with fault isolation resistors and a step-up transformer (1:1.41) to avoid shorts, improve common mode rejection, and provide lightning immunity for the terminals connected to the bus.

Balancing the Amount of Couplers and the Distance between Them

While bus couplers are necessary to protect the internal wiring and circuitry, they inevitably add a degree of mismatch. The main bus (often 78 Ω twinax) has a consistent impedance along the transmission line until a stub where the discontinuity causes an abrupt change in impedance resulting in reflections and loss. MIL-STD-1553B specifies that the longest stub length is 20 feet for transformer coupled stubs in order to minimize the impedance load on the main bus. Still, this number can be exceeded as there is a delicate balance in introducing loads on the bus in order to achieve the specified signal-to-noise ratio and systems error rate performance as specified in MIL-HDBK-155A.

The effect the stub has on the bus waveform depends on the rise/fall time as compared to the time it takes for a wave to propagate from the bus to the end of the stub and back. The reflection can occur before the waveform has changed, causing waveform distortions. In essence, a high impedance of the coupling stub can minimize signal distortion but since this impedance is reflected back to the main bus, the impedance has to be kept below a certain threshold in order to deliver an adequate amount of power at the receiving end. The total load and total characteristic impedance can potentially have an adverse effect on the performance of an installation. Oftentimes, it is desirable to have reserve couplers in order to access extra remote devices whenever deemed necessary. Still, the hazard that the extra load can cause makes it so that reserve couplers are not used in a bus line system unless absolutely required [4].

In-Line Stub Coupler

In-line couplers are spliced directly into the main bus cable, this allows for small form factors and weight savings when compared to the box style stub coupler, these couplers can be conveniently rolled up in wiring bundles without the need to preplan the arrangement of couplers. Highly integrated wiring systems

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in small aircraft may require in-line couplers due to their limited weight requirements to maintain the desired power-to-weight ratio. This comes with the cost of modularity as the in-line stubs are often difficult to repair/replace in the case of a failure due to a lack of transformer integrity where the windings could be open or shorted. During installation, a complete cable harness cannot be dismantled and reorganized due to unexpected circumstances (damage during fitting) by the operators in charge of fitting the equipment--potentially costing more in time and pushing back deadlines for aircraft construction. This can be inhibit productivity on the industrial scale as the exact arrangement of the aircraft components and interconnections must be thoroughly gauged in order for the whole process to run smoothly.

In-line couplers have the benefit of high reliability and space savings with the tradeoff of flexibility during installations and overhauls.

Box Stub Coupler

Boxed couplers can be an asset in that they are relatively simple install and replace thereby mitigating any hassle that can occur upon installation. Still, designers must plan for mounting points for couplers and their respective wiring as the bulky housing occupies much more space and weight. The splicing necessary to install a boxed coupler is more unreliable as there are far more connections between the bulkhead connectors on the box and the clamp/solder or crimp joints of the wiring. These connections can quickly fatigue under the duress of an aircraft's high vibration environment increasing the mean times between failures (MTBF). MTBF is a direct measure of a system's reliability based on known failure rates of subassemblies in a 1553B network, this indicator is also directly proportional to the number of components and joints between each component. In the occurrence of a fault, technicians connect bus analyzers to the twisted shielded pair bus and twist and wring the wires in order to locate the source of the short. This can further damage the bus wires posing another potential risk for failure to a network installation [1].

Couplers housed in boxes allow for a highly modular configuration in aircraft but the increase in connections can decrease their level of reliability as compared to in-line stubs.

Multi-Port Couplers

Since there is no specification for the minimum distance between stubs on a bus, multiple stub output couplers are employed to connect to a tight grouping of avionics to potentially save space, weight, and improve MTBF as this solutions limits the amount of individual stubs necessary. While these also come in in-line form factors for intricately designed aircraft wiring, the box style couplers have the benefit of saving on space while maintaining modularity and ease of installation and repair.

Harness Considerations

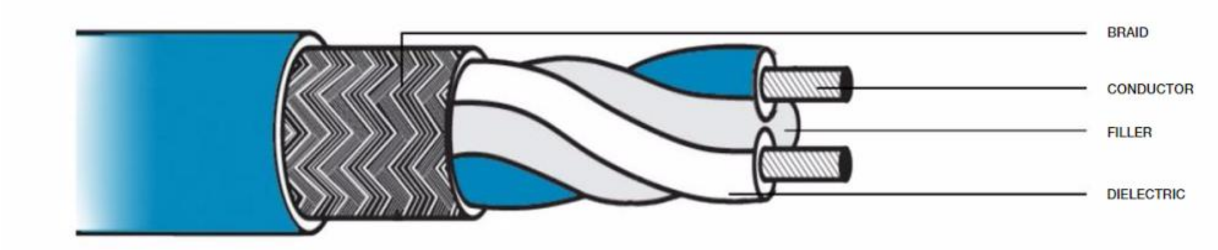
Cable Length

Typically, most of the cable runs in a 1553B installation consists of the main bus, or, a twisted shielded pair with an impedance between 70 Ω and 85 Ω (typically 78 Ω). The maximum attenuation specified for the cabling is 1.5 dB/100 feet at 1 MHz, for longer cable runs a lower attenuation is necessary. In other words, the maximum length of the bus is directly correlated to the gauge of the inner conductors and time delay of the transmitted signal.

According to MIL-HDBK-1553A Section 40.6.1, when a signal's propagation delay is more than 50% of the rise or fall time, it becomes necessary to consider transmission line effects such as attenuation. The average rise time of a 1553B signal is 1.6 nanoseconds/foot so a 100 foot bus would have a 160 nanosecond propagation delay.

Twinaxial Cable Electrical Considerations

Twinaxial cables are normally leveraged for the main data bus in a 1553B network, this is due to their effectiveness for short-range, high-speed, differential signaling applications up to 15 MHz. A minimum of 90% coverage is specified in MIL-STD-1553B for enhanced RF/electromagnetic interference (RFI/EMI) protection. While the two balanced signals running through the twisted pair cancels any randomly induced noise picked up through the copper braid, optimizing the braid and dielectric of the twinax can still greatly improve some of its electrical characteristics. Braiding can be made of a variety of metal alloys but copper still has the best conductivity and therefore provides higher coverage, the coverage can be further improved to up to 93% by weaving the braid tighter. This level of craftsmanship in the manufacturing process can enhance performance without leveraging any extra materials. Another option to improve performance is to add an additional dielectric filler to separate the braid from the twisted pair and lower leakage capacitance to ground, this is especially useful in long runs where the longer conductors have a higher capacitance.



Twinaxial cables have balanced conductors that leverage differential signaling where any external common-mode noise can easily get canceled. Additionally 1553B twinaxial cables require a minimum of 90% coverage, further increasing noise immunity.

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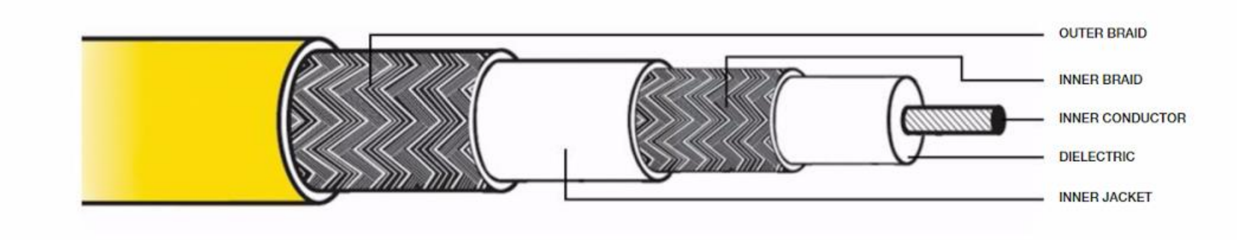
Triaxial Cable Electrical Considerations

Typically used for sensitive and wideband systems where noise voltages arising from stray power sources is of concern such video and high frequency data circuits, triaxial cables are more similar to a coaxial cable with an extra layer of dielectric and shielding. The grounded outer braid adds the ability to pass both ground loop and capacitive field noise currents from the internal coax. At high frequencies, the cable reduces the shield surface transfer impedance due to the isolation and decoupling between the two braids [5]. While this additional layer provides greater bandwidth and interference rejection, it is more expensive than the twinax and coax and so is typically used in specialized systems such as low-impedance laser lamps and exploding bridge (EBW) ordinance systems [6].



Discrete triaxial cabling is leveraged for specialized high frequency applications where the second layer of shielding is chassis ground while the inner braid functions as the return path for the signal. This provides protection from common-mode interference.

Multiple Signal Harnessing Considerations

The interconnections between avionics equipment often require the use of cable harnesses for multiple discrete signals. These cables require extra care so that the signals transmitted are not interrupted or obscured by external noise. Oftentimes, twisted shielded pairs are leveraged for the benefits of differential mode transmission where common-mode signals can be readily distinguished and canceled as well as added shielding to provide EMI protection. The shielding is then stripped back and the twisted pair unfurled in order to crimp or solder connector pins and ground the shielding (or generate another pin). For the isolation of signals, when a number of signals pass through a single connector wires that carry similar signals are often laced separately in the harness. In some cases multiple floating shields have the potential to cause ground loops and can be avoided by being properly terminated with conductive RFI/EMI backshell adapters and large compression rings.

Multi-pin cable harnesses that route discrete signals between avionics equipment often use twisted shielded pairs with triaxial connector pin inserts as the concentricity ensures the polarity of cables from two different vendors are not reversed.
Source: http://www.navair.navy.mil/index.cfm?fuseaction=home.NAVAIRNewsStory&id=5594

Cable Jacketing and Insulation

While the electrical performance of the harnessing is critical, the mechanical reliability of the cabling can be just as relevant in the performance of a data bus. Cable jacketing is the first line of defense of a cable from harsh environments and temperature extremes. Military cables are often designed to withstand temperatures between -55ºC to 125ºC particularly in high altitude applications. Polymers such as Teflon (PTFE) are often leveraged for its strength and elasticity in a wide range of temperatures. Materials such as perfluoroalkoxy (PFA) for cable jacketing and fluorinated ethylene propylene (FEP) for insulation have been introduced for their ability to function at extremely high and low temperatures (from -55ºC to 200ºC). Jacketing materials that cannot withstand extreme temperature cycling will eventually swell, crack, or deform creating intermittent signals or even complete signal loss. Low smoke zero halogen (LSZH) jacketing can also be necessary in vehicles with low ventilation as some jacketing materials become highly reactive when burned producing toxic fumes that pose a danger to any inhabitants in the closed space.

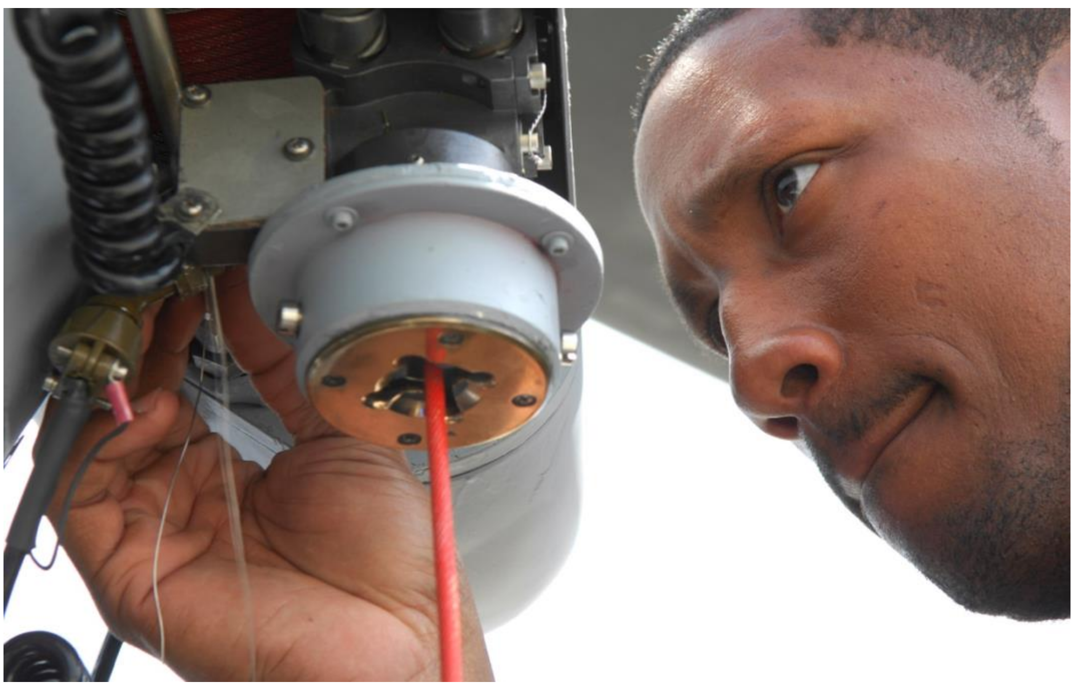
Connector Considerations

MIL-STD-1553B does not directly specify the type of connector that must be used to connect cabling with the exception of the polarity of a concentric connector. There are essentially two types of connectors:

multi-pin connectors (shapes including circular, rectangular, and rack and panel), and discrete concentric triaxial design (threaded and bayonet). As specified in MIL-HDBK-1553A, the ideal method for carrying a bus through a multipin connector through the use of a triaxial contact since these terminate the twisted pair coaxially and terminate the braid through 360 degrees with nearly 100% coverage.

Discrete Concentric Threaded

Threaded connectors have the benefit of a straightforward design that can be used in many applications although connectors from different vendors may not be intermateable. Threaded connectors present a disadvantage in tight spaces where there is not enough leverage to torque a connector properly and blind mating may be necessary. A major concern for interconnect on an aircraft are connections coming loose due to vibrational strain. Oftentimes, technicians will leverage safety wire to prevent this occurrence. Still, the wire itself simply maintains tension by being twisted around itself to prevent demating, the actual connector must maintain the torque in order to stay fastened to prevent an intermittent connection. Cross-threading is another concern for unintentionally forced mates between two unmateable connector heads ultimately damaging threading.



Caption: Threaded connector heads can often be fitted with safety wire to prevent demating under high shock and vibrational strain particularly in helicopters.

Source: http://www.af.mil/News/Photos.aspx?igphoto=2000637121

Discrete Concentric Bayonet

Bayonet type connectors have the advantage of simple, repeatable installation without the need for safety wiring as vendors can employ multiple lugs where the center contact and a second intermediate cylindrical contact can maintain engagement. This type of connector head is most often used for the twinax main bus as it does not need the same torsional strain as a threaded connector for reliable contact, this is particularly beneficial in tight spaces. It is also important to note that along with the diversity of vendors offering bayonet connectors comes the diversity in mating surfaces that are not intermateable and also not able to support the keying requirements for some systems.

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Conclusion

Practical concerns such as the simplicity of fitting connections versus the reliability of the connection can be addressed during the design of the wiring arrangement in a 1553B network prior to installation. While using box style couplers and bayonet adapters may increase simplicity and modularity, the reliability of the interconnect can go down as the MTBF increases as well as the risks posed when obtaining bayonet connectors from various manufacturers. Beside what is directly specified in MIL-STD-1553B, the type of coupler and cable assembly leveraged is highly dependent on the type of signal and layout of the vehicle.

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