

Considerations for Testing and Simulation of MIL-STD-1760E/HS1760 Avionics Interfaces

Troy Troshynski
Avionics Interface Technologies
(A Division of Teradyne)
Omaha, NE U.S.A.

Abstract— MIL-STD-1760, a Department of Defense Interface Standard, was developed to reduce the proliferation of interfaces between aircraft and their stores, and instead to promote interoperability between weapons and aircraft platforms. The original version of the MIL-STD-1760 defined a standardized electrical interface and connector that included both digital and analog databuses, a standardized message protocol (MIL-STD-1553), power, and discrete signals. In 2007, the latest version of MIL-STD-1760 was released. MIL-STD-1760E, employed the previously unused High Bandwidth 2 and High Bandwidth 4 pins of the standardized MIL-STD-1760 connector. These pins were utilized to carry a Fibre Channel based high speed digital databus, FC-AE-1553 which is an adaptation of MIL-STD-1553 for Fibre Channel. This paper provides a brief technical overview of the HS1760 databus and related standardized protocols and also provides an overview of the key technical considerations that must be accounted for when designing test and simulation equipment used to test various aircraft systems and stores which employ the MIL-STD-1760E interface.

Keywords—MIL-STD-1760E, HS1760, AS5653, Fibre Channel, MIL-STD-1553, FC-AE-1553, Avionics

I. INTRODUCTION TO MIL-STD-1760

The MIL-STD-1760 interface standard was created to standardize the electrical (and fiber optic) interconnect between an aircraft and its stores. Aircraft stores are any device intended to be carried externally on the aircraft. Stores can be weapons, auxiliary fuel tanks, and sensor pods all of which can be controlled from the aircraft.

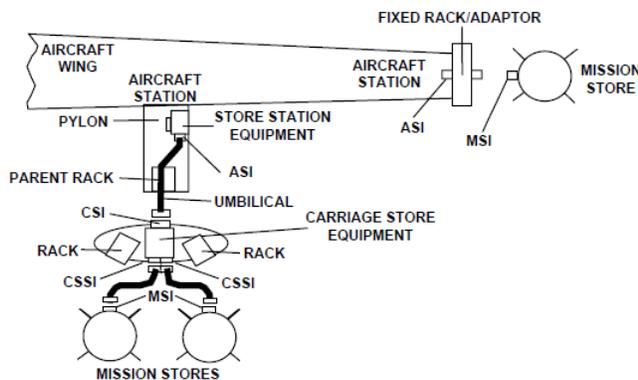


Fig 1- MIL-STD-1760 Interfaces

As shown in Fig 1, MIL-STD-1760 provides for a variety of aircraft/store configurations. In the most simple case, the standard defines the requirements at the Aircraft Station Interface (ASI), and the Mission Store Interface (MSI). For more complex structures where an external rack is used to host multiple stores, the standard defines the requirements also at the Carriage Store Interface (CSI), and the Carriage Store Station Interface (CSSI).

The ASI, MSI, CSI, and CSSI are all required to implement a Primary Interface signal set and can optionally implement an Auxiliary Power signal set. The Primary Interface consists of Signal Lines, Discrete Lines, and Power Lines

The Signal Lines of the Primary Interface include four High Bandwidth (HB) signal lines, two Multiplex (MUX) data bus interface lines, two Fiber Optic lines, and one Low Bandwidth (LB) line. The MUX lines are used for a 1MHz redundant MIL-STD-1553 interface between the aircraft and the store. The HB lines were originally included in the aircraft/store interface to carry higher bandwidth (above 1MHz) signals over an electrical interface. Two of the HB interface lines (HB1 and HB2) are required to have a 50 Ohm characteristic impedance and the other two (HB3 and HB4) are required to have a 75 Ohm characteristic impedance.

II. INCREASING BANDWIDTH WITH MIL-STD-1760E

In 2007, an updated version of the MIL-STD-1760 standard was released, MIL-STD-1760E. This new version of the standard was primarily driven by the ever increasing need for additional bandwidth for signals between the aircraft and the store driven by more complex aircraft systems, weapons, and sensors.

While the earlier versions of the MIL-STD-1760 left the HB signal lines largely undefined and unused in real applications, MIL-STD-1760E clarified the use of these lines to carry the high speed signaling interface defined in SAE AS5653. MIL-STD-1760E redefined the HB2 signal to the Up Fibre Channel signal and the HB4 to the Down Fibre Channel signal. The electrical interface and characteristics of these signals were not changed and remained compatible with earlier versions of the interface specification.

A. HS1760 (SAE AS5653)

AS5653 is commonly known and referred to as High Speed 1760, or HS1760. The new data bus uses 75 Ohm Coaxial cable with 2.5 V_{PIP} signaling. This was found suitable for operating Fibre Channel at 1.0625 Gbps with up to 100 feet of cable including 5 cable disconnects. AS5653 specifies that the Upper Layer Protocol (ULP) to be used for command, control, and file transfer is to be Fibre Channel’s FC-AE-1553 protocol. FC-AE-1553 can be thought of as a mapping of MIL-STD-1553 over Fibre Channel. AS5653 also specifies the use of other ULPs for the purpose of transferring video streams between the store and the aircraft.

1) Profiled Fibre Channel

AS5653 is a profiled Fibre Channel protocol. That is, AS5653 largely defines a subset of the available Fibre Channel protocol options that are to be used in avionics applications. The Fibre Channel protocol was originally focused on providing a high performance and high reliability interconnect between processors and secondary storage. It’s origins were driven by the needs of Storage Area Networks (SAN).

For typical SAN applications, systems are very large consisting of hundreds (or thousands) of interconnected nodes from many different vendors. In this dynamic environment, adaptive behavior and Plug-and-Play type operations are desired to mitigate the complexity of managing such large networks. Also, this type of application typically measures real-time behavior in tens of milliseconds. By contrast, typical avionics applications of Fibre Channel type networks are characterized by a much more static and contained environment with a fixed and smaller number of nodes from a smaller number of vendors. In avionics applications, real-time is typically measured in tens of microseconds. The principle of AS5653 is to profile Fibre Channel for use avionics applications where the network is more basic, more static, and requires lower latencies and more determinism.

2) A Simplified Fabric

For HS1760 and other avionics applications, a new fabric initialization protocol was defined. Fast Fabric Initialization (FFI) takes advantage of the reduced complexity of avionics type Fibre Channel networks and allows these types of networks to initialize in a fraction of the time of their commercial counterparts and FFI allows the fabric initialization time to be deterministic.

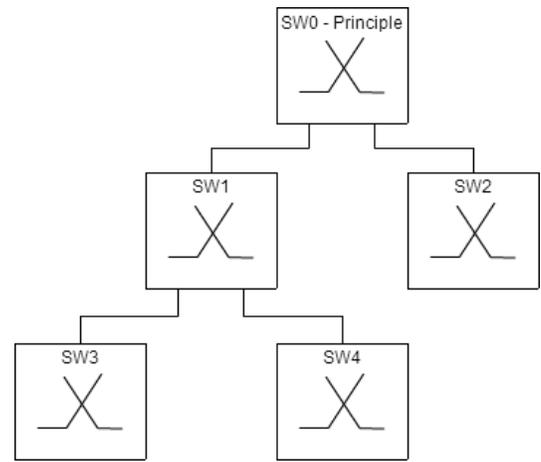


Figure 2 Fabric Tree Structure

In HS1760 applications, the fabric is only allowed to be structured as a tree as shown in Fig. 2. The switch at the head of the tree is the principle switch. The principle switch is statically configured with the Domain Topology Map for the entire network. At startup, the principle switch distributes the Topology Map to the downstream switches in the fabric. The topology map contains the statically allocated addressing for the nodes of the network.

B. FC-AE-1553

HS1760 specifies FC-AE-1553 as the ULP to be used for command/control, and file transfer over the aircraft to store interfaces. FC-AE-1553 can generally be thought of as a mapping of MIL-STD-1553 onto a Fibre Channel network. Just like MIL-STD-1553, FC-AE-1553 uses a command response protocol with a controller (Network Controller) initiating read and write commands to the terminal (Network Terminals).

	MIL-STD-1553	FC-AE-1553
Speed	1 Mbps	1 Gbps
1553 Bus Entities	Bus Controller Remote Terminal RT Subaddress	Network Controller Network Terminal NT Subaddress
Full Duplex	No	Yes
Address Range	31 RTs 30 SAs per RT	16M NTs (24-bit Addr) 4G SAs per NT
Bytes per Message	Upto 64 bytes	Upto 128 MB
Bus Length	100 Meters	Unlimited with switched topology
Drop/Stub Length	3 Meters	30 Meters

Table 1. MIL-STD-1553 vs FC-AE-1553

FC-AE-1553 provides a much larger addressable range of terminals and terminal subaddresses than MIL-STD-1553 as shown in Table 1. However, for compatibility with existing MIL-STD-1553 applications, the Subaddresses 1 to 30 are left reserved in FC-AE-1553. Also, in addition to the command/response protocol, FC-AE-1553 also includes

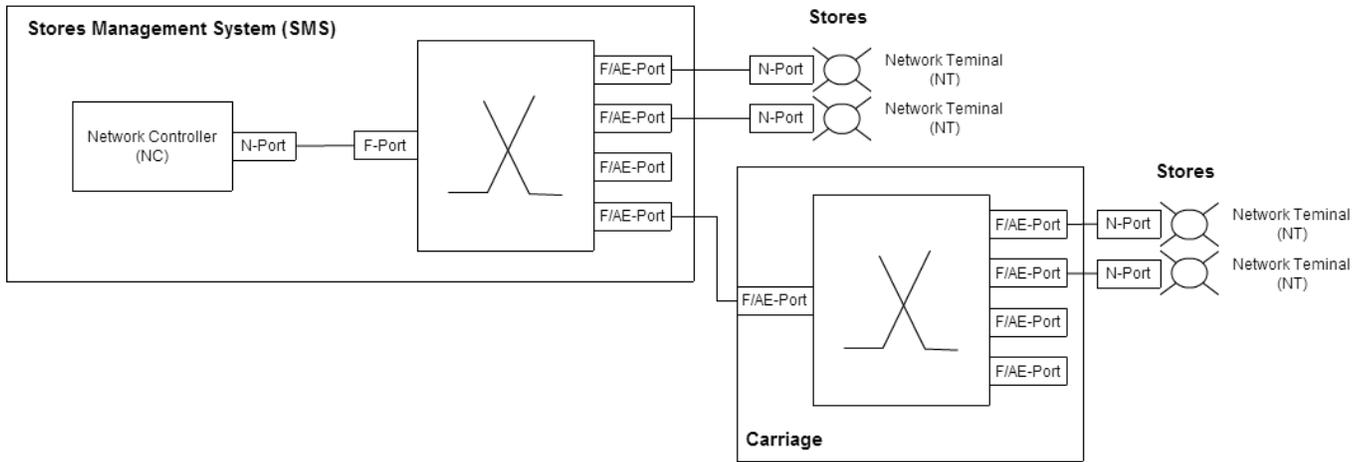


Figure 3 HS1760 System

provisions and protocol options to support file transfers and mass data transfers in order to support more efficient data loading type applications.

III. HS1760 TEST AND SIMULATION

A. Test Scenarios

HS1760 test equipment and test systems must be capable of providing support for the FC-AE-1553 Network Controller (NC) and Network Terminals (NT) as well as the avionics environment (AE) switch interfaces. Several test scenarios must be considered when designing test systems. For example:

- Testing at the interface to the stores
- Testing at the interface to the aircraft Stores Management System (SMS)
- Testing at the interfaces to a carriage

The Fibre Channel protocol defines several port types which are used for interfaces between nodes and switches. The details and requirements of the communications are defined based on the connected port types. In an HS1760 network, several port types must be considered.

1) N-Port

A Node Port is a port that resides at an end node such as a store. An N-Port connects to a fabric (fabric topology) or another N-Port (point-to-point topology).

2) F-Port

A Fabric Port is a port on a switch that connects to a node.

3) F/AE-Port

A Fabric/Avionics Environment port is a switch port that can support either connections to a node (acts like an F-Port) or to another AE switch.

Fibre Channel defines several other port types, for example to support arbitrated loop topologies. These additional port types are not mentioned here because they are not allowed in HS1760 networks. Fig 3 shows the location that the port types reside within a typical HS1760 network.

B. Testing HS1760 Stores

An HS1760 aircraft store operates as an FC-AE-1553 NT and is controlled by the SMS which acts as the NC. To test a store the test system must be capable of simulating the commands of the SMS NC. In the most simple HS1760 network scenario, the SMS can connect to the store via a point-to-point Fibre Channel connection. However, more commonly the NC of the SMS will be connected to multiple stores via a fabric.

Note: fabric switches are commonly capable of supporting point to point topologies and functioning as a hub which simply provides an interconnect between N-Ports at the end nodes

In order to have the capability to test all of the possible interface types at the MSI, the test system must have the capability to connect to the store using either Fibre Channel point-to-point or fabric topology.

C. Testing Stores Management Systems

A test system used to verify the operations of an SMS must have the capabilities to simulate the interface to both stores and to carriages at the ASI. For this testing scenario, the test system must have the capability to act as an N-Port and an FC-AE-1553 NT to simulate a store. The test system must also have the capability to act as multiple NTs and to present an F/AE-Port to the SMA ASI interface.



Figure 4. AS5653 Compliant SFP Transceiver

D. Testing the Carriage

To test an HS1760 Carriage, the test system must have the capability to simulate the signals at the CSI and CSSI. At the CSI, the test system will be required to simulate the FC-AE-1553 NC of the SMS as well as the F/AE-Port functions of the SMS AE switch. On the stores side of the carriage, the test system must simulate the N-Port and NT of one or more stores that may be attached to the carriage.

This can most easily be achieved by employing the use of a Small Form-factor Pluggable (SFP) transceiver capable of the 2.3V signaling over coaxial cables. Most Fibre Channel interface hardware provides SFP receptacles which can be used to host SFP transceivers.

IV. HS1760 TEST SYSTEM DESIGN

A. Test Equipment Connections

The HS1760 profile of Fibre Channel defines a 2.5 V_{PP} electrical signal over 75 Ohm coaxial cabling rather than the more commonly used optical media employed in Fibre Channel applications. Any HS1760 test and simulation equipment must therefore have the capability to communicate with the unit or systems under test over this electrical interface.

B. End Node Simulation

As shown in Table 1, the FC-AE-1553 protocol provides for much larger data transfers and a much larger addressable range of the terminals and sub addresses at each terminal when compared to MIL-STD-1553. It also provides for much higher data transfer rates.



Figure 5. PXI Express HS1760 Test Instrument



Figure 6 16 Port Avionics Environment Lab Switch

With these protocol enhancements in mind, it becomes clear that any test equipment used to support HS1760 verification activities must be implemented on latest high speed test system platforms. A PXI Express based system is an ideal solution which can provide up to 8GB/sec of dedicated bandwidth to each test instrument. The PXI Express instruments should be used to provide FC-AE-1553 NC and NT functions. The test instruments must also provide SFP receptacles in order to be capable of hosting the AS5653 SFP transceivers required to interface to the HS1760 75 Ohm coaxial electrical interface. The test instrument must be capable of providing support for both the point-to-point and fabric topologies.

C. Avionics Environment Switches

For more complex test scenarios and system integration and simulations, the test system may require an avionics environment switch capable of FFI. The switch could be used together with the PXI Express test instrument, acting as an NC, to build a simulated SMS capable of interfacing to one or more stores.

The switch could also be used together with the PXI Express instrument(s) to emulate a carriage with attached stores. In this case, with an SMS as the unit under test, the lab switch would provide an F/AE-Port interface to the SMS. PXI Express instruments, operating as NTs, connected to the switch would simulate the downstream stores.

V. CONCLUSIONS

The latest version of MIL-STD-1760, MIL-STD-1760E, provides a new high speed signaling interface for increased bandwidth between the aircraft and external stores. While this interface has been designed to be fully compatible with existing interface signals and connectors, it has also provided support for additional configurations of carriages and stores by introducing the option of a switched network architecture rather than a just the shared bus architecture provided by MIL-STD-1553. It has also introduced new protocols such as FC-AE-1553 into the interface. As a result of these upgrades, test system designers must consider the demand for increased bandwidth in systems used to support design and verification of HS1760 stores and stores management systems. Additionally, the test system designers must also consider the requirements to support new upper layer protocols such as FC-AE-1553 and also less common electrical interfaces such as the 75 Ohm coaxial interface employed by HS1760.

VI. REFERENCES

- [1] INCITS TR-42-2007 , INCITS Technical Report for Information Technology-Fibre Channel-Avionics Environment-Upper Layer Protocol (FC-AE-1553),
- [2] MIL-STD-1760E, 25 October 2007
- [3] AS5653B, High Speed Network for MIL-STD-1760, 03 January 2014

© 2015 IEEE. Personal use of this material is permitted. Permission from IEEE must be obtained for all other uses, in any current or future media, including reprinting/republishing this material for advertising or promotional purposes, creating new collective works, for resale or redistribution to servers or lists, or reuse of any copyrighted component of this work in other works.