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Multiplex Data Bus Networks for MIL-STD-1760 Stores

FOREWORD

Changes in this reaffirm are format/editorial only.

1. SCOPE:

This SAE Aerospace Information Report (AIR) will examine network aspects of open and shorted stubs, line reflections and bus loading due to network changes. Single network level is assumed, that is, no carriage store hierarchical levels. However, two passive network coupling variants called "branched bus" and "branched stub" will be introduced that possibly could be used in a stores management network.

This report assumes familiarity with MIL-STD-1553B.

1.1 Purpose:

This document summarizes the results of hardware tests on simulated weapon data bus networks utilizing MIL-STD-1760 (Reference 2.2.1).

Unique to this application is the fact that the network is reconfigurable by connecting together mission dependent MIL-STD-1553B (Reference 2.2.2) store remote terminals (RT)s at artificial network breakpoints. Further, during normal data bus operation the weapon RTs are physically removed from the network. That is, in-flight weapon separation from aircraft results in "open stubs" on the bus network. See Figure 1. All this gives rise to changing network conditions, stubs exposed to harsh environments (such as during rocket motor firing), noise interference, interoperable store requirements for US/NATO military services and controversy about the effect of "open stubs" on bus performance.

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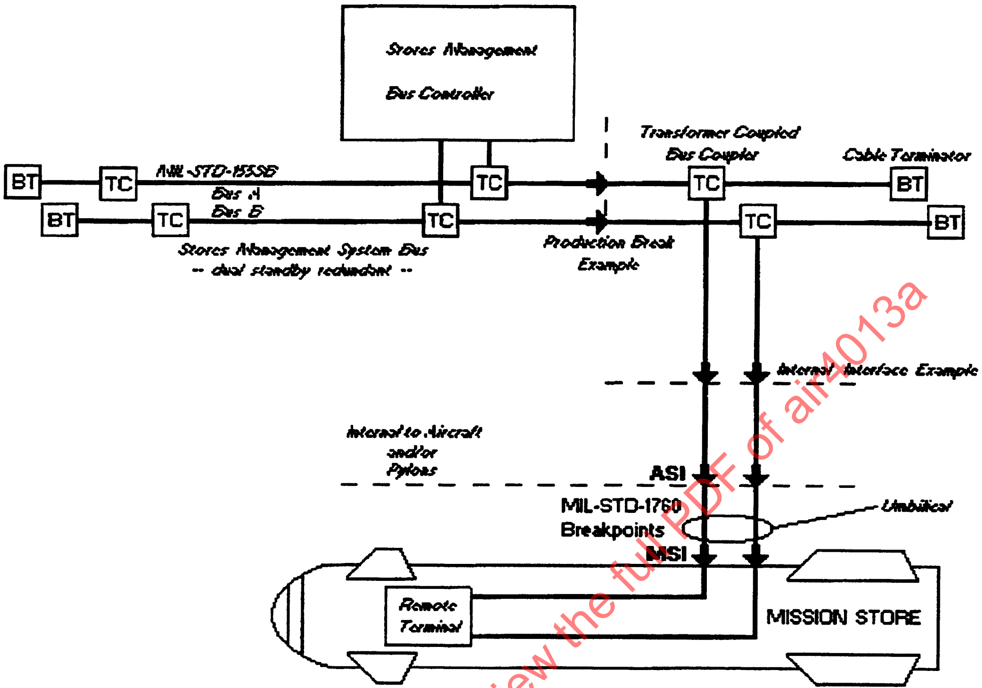

FIGURE 1 - Basic Stores Management System Bus Network

2. REFERENCES:

2.1 SAE Publications:

Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096.

2.1.1 Aircraft/Stores Data Bus Networks, Paper Number 860842, SAE Aerospace Avionics Equipment and Integration Conference Proceedings P-179 (24 April 1986)

2.2 U.S. Government Publications:

Available from DODSSP, Subscription Services Desk, Building 4D, 700 Robbins Avenue, Philadelphia, PA 19111-5094.

2.2.1 MIL-STD-1760A through MIL-STD-1760C Aircraft/Store Electrical Interconnection System

2.2.2 MIL-STD-1553B Digital Time Division Command/Response Multiplex Data Bus

3. GENERAL COMMENTS:

The terms used in this report are consistent with MIL-STD-1760. The network is used for control and monitor of interoperable stores (missiles, bombs, pods) mounted either internal or external to aircraft. The current means for store control and status is through the use of MIL-STD-1553B.

3.1 Stores Management System (SMS) Bus Network:

Most of the MIL-STD-1553B SMS bus network is located internal to the aircraft as illustrated in Figure 1. To preserve bus integrity, the bus should cross as few internal aircraft separation planes as possible. The bus coupler and stub wiring to the Aircraft Station Interface (ASI) would be enclosed in the aircraft. However, unused ASI connectors and ASI to Mission Store Interface (MSI) umbilicals would be exposed to the separation event. Additionally, for externally mounted stores, the ASI to MSI path may be exposed to harsh environments over long time periods. The path from the MSI store connector to the remote terminal would be internal to the store. For example, in the AMRAAM missile (AIM-120) the internal cable length to the RT is about two feet.

3.2 Waveform Envelope:

MIL-STD-1760 defines the ASI output characteristics as a waveform envelope varying from a square wave to a sine wave with peak-to-peak, line-to-line amplitude between 1.4 and 14 volts. MIL-STD-1553B transformer coupled remote terminals must be able to operate with these signals as low as 0.86 volt peak-to-peak. This allows a margin of 0.54 volt peak-to-peak for possible signal attenuation and noise injection between the ASI and the store RT.

4. DISCUSSION:

Initial SMS network loading depends upon the number and type of stores connected to the network. Different missions may result in different initial bus loading. During mission operation, the network loading changes as stores are released. Normally, the network loading decreases as the stubs go open circuit (open); however, loading can increase considerably if the stubs become short circuit (shorted). Traditional MIL-STD-1553B avionic networks have constant loads and therefore are not subject to the dynamic environment of SMS networks.

4.1 Open Stubs:

Each loaded stub normally becomes an "open" stub when its store RT is disconnected from the network. This action results in a slight increase in signal amplitude at all other RTs still connected to the network. The resulting increase in signal amplitude does not degrade the performance of the network due to the fact that MIL-STD-1553B networks typically operate with signal amplitude considerably below the maximum acceptable level. In those situations where multiple RT stores are released and their stubs "open" simultaneously, the resulting increase in signal amplitude is still rather insignificant (typically less than 5%). Network radiated emissions and/or susceptibility caused by antenna effects of a stub "opened" at the MSI appear to be negligible due to the small size and coaxial arrangement of the inner and middle members of the triaxial contacts. The change in reflections at the coupler is also small. See the discussion on coupler spacing (see 4.5). The conclusion is that isolation techniques or resistor termination schemes after store separation do not seem to be necessary. The bus network will continue to operate with multiple open stubs.

4.2 Shorted Stubs:

If a transformer-coupled stub is "shorted" during the release of its store RT, additional loading is placed upon the network resulting in lower signal amplitude at all other RTs. If the signal amplitude had been only slightly above the threshold level of an RT before "shorting" of a stub, this action could result in word errors and/or missed words at the RT. Multiple "shorted" stubs can reduce the signal amplitude of the network significantly (typically greater than 20%). This amount of signal degradation could be devastating.

Since stubs can be "shorted" during the release of a store due to metallic particles from rocket motor exhaust plumes and/or melted connector pins, it is strongly recommended that the network design be tested with the maximum number of anticipated "shorted" stubs - not just the one "shorted" stub required by MIL-STD-1553B. During this abnormal operation of shorting stubs while stores are releasing from the network, the bus controller protocol may require special processing (such as more retries or inhibit transmission) so that other RTs on the bus are not faulted.

4.3 Store RT Output:

To improve the performance of SMS bus networks, MIL-STD-1760 requires a minimum transmitted output of 20 volts peak-to-peak for all store remote terminals measured at the MSI (MIL-STD-1553B requires a minimum of eighteen (18) volts peak-to-peak). This higher output voltage helps to overcome the signal attenuation associated with large, heavily loaded networks.

4.4 Transceiver Types:

At present, there are two types of MIL-STD-1553B transceivers: constant current and constant voltage. Both have worked well in systems encountered to date. However, the advent of MIL-STD-1760 is changing the nature of MIL-STD-1553B networks from small static to large dynamic loads. Constant current transceivers will not handle varying loads as well as constant voltage transceivers. The output voltage of a constant current transceiver varies inversely with the changing load. This could lead to signal amplitude problems on heavily loaded SMS bus networks. Built-in current limiting is advisable for either type of transceiver for overall protection.

4.5 Bus Coupler Spacing:

Classical transmission line theory states that impedance mismatches on a transmission line generate reflected waves. The mismatches caused by couplers in a MIL-STD-1553B network produce reflections which affect the shape of the signal waveform. As coupler spacing decreases, the leading edge of the waveform becomes distorted but the signal amplitude is not reduced. Therefore, coupler spacing (evenly distributed versus lumped together, up to 7 in reference 2.1.1) appears to have little effect on bus performance.

System implementation may make it desirable to collocate the couplers (lumped) to handle multiple store stations in the confines of a pylon or rotary launcher.

4.6 Unique Configurations:

SMS network configurations are more complicated than fixed avionics networks due to physical limitations of aircraft volume constraints and interface requirements of removable components such as rotary launchers and pylons. In addition, lower level multiple store stations such as multiple carriage bomb racks, may require communication from a single ASI. One solution is to use a hierarchical bus structure with a "bridge" terminal which acts as a remote terminal on the stores management bus and a bus controller on a lower level bus to mission stores. It isolates the buses, reducing dynamic loads and allowing more stations than a single bus. However, this method will complicate the communication protocol and lengthens data transfer times.

This section introduces two design solutions that may be more applicable to SMS configurations: branched stub and branched bus.

4.6.1 Branched Stub: The branched stub is intended to support mutually exclusive ASIs. It is implemented as a standard transformer coupled MIL-STD-1553B bus coupler with two or more stub allocations as shown in Figure 2. This multi-stub configuration can offer convenient ASI connector access for present or future systems. The MSI can thereby interface with the most physically convenient ASI. With only one connection used, and the unused connections left unterminated, the branched stub does not violate MIL-STD-1553B.

4.6.2 Branched Bus: The branched bus permits the extension of an inplace MIL-STD-1553B stores management bus. See Figure 2. For applications where multiple RTs are located across an aircraft separation plane (such as a wing-pylon), it is preferred not to daisy chain the bus down and back across trouble prone separation planes. The branched bus preserves bus reliability and eliminates the need to have long multiple stubs crossing the separation plane.

4.7 Electromagnetic Environment (EME):

Considerable protection from EME is provided with the use of coupling transformers and the shielded twisted pair cable mentioned in MIL-STD-1553B. Further protection is provided with the reference 2.1.1 MIL-C-38999 connector and receptacle configuration. This configuration uses the concentric M-39029/90-529 (pins) and M-39029/91-530 (sockets) configuration for the data bus interface. However, networks for stores will be subjected to rather severe EME and will probably require additional shielding to survive lightning waveform threats, electromagnetic pulse (EMP) and electrostatic discharge (ESD). In addition, the new nonmetallic aircraft skin and structure designs compound the EME problems. Care must be taken in the use of EME filter techniques. Certain transient protection devices may adversely load the network due to their high capacitance.

5. CONCLUSIONS AND RECOMMENDATIONS:

Based upon bus network test results (Reference 2.1.1), the 20-foot maximum stub recommendation in MIL-STD-1553B can be exceeded in properly designed and tested SMS bus networks.

5.1 Dynamic Networks:

Network test results indicate that the "open stub" issue is not a problem. Reflections and EME susceptibility due to unterminated couplers do not appear to degrade bus network performance. The reduction of bus network loading slightly increases signal amplitude. The real issue is that a SMS bus network may experience multiple shorted stubs.

Both transceiver types (see 4.4) will operate in a SMS bus network. However, the constant voltage transceiver exhibits a higher degree of interoperability. Although it is slightly larger in size (1/3 to 1/2), the constant voltage transceiver is less prone to amplitude degradation caused by increasing network loads (including multiple shorted stubs).

5.2 SMS Network Coupling:

Conclusions based on distributed versus lumped coupler tests are that collocated couplers are feasible and practical for SMS applications. Where multiple stubs would be required to cross separation plane, the branched bus offers a simple solution.