AVIONIC SYSTEMS STANDARDISATION COMMITTEE

ASSC

Doc No : ASSC/110/2/124

Issue 2– September 2003

TEST PLAN FOR FAULTFINDING IN INSTALLED DEF-STAN 00-18 (PART 2) BUS NETWORKS

Table of contents **Page no.**

Table of contents **Page no.**

Table of tables **Page no.**

Table of figures **Page no.**

1 Introduction

This Test Plan outlines tests that may be carried out on installed DEF-STAN 00-18 (Part 2) bus networks to assist operational investigation, testing and fault finding. Further information on the validation of this Test Plan will be found in 3 Related Documents (j).

2 Scope

2.1 Purpose

This test plan defines tests to be performed on installed DEF-STAN 00-18 (Part 2) bus networks to assist in investigation of incorrect or unreliable (e.g. high error rate) system performance when the bus hardware is suspected of being the cause.

2.2 Application

This is a general test plan for fault finding on any data bus network designed to meet the requirements of DEF-STAN 00-18 (Part 2).

3 Related Documents

The following standards and reports are relevant:

(a) Def Stan 00-18 (Part 2): Serial, Time Division, Command/Response, Multiplex Data Bus.

(b) STANAG 3838 AVS: Digital Time Division Command/Response Multiplex Data Bus, with Amendment 1.

(c) US MIL-STD-1553B: Digital Time Division Command/Response Multiplex Data Bus. (21 September 1978 with Notice 2, 8 September 1986)

(d) US MIL-HDBK-1553A Multiplex Applications Handbook

(e) SAE AS4112 RT Production Test Plan

(f) SAE AS4113 BC Validation Test Plan

(g) SAE AS4114 BC Production Test Plan

(h) SAE AS4115 System Test Plan

(i) BCF Designs Ltd., Evaluation of a TDR to Fault Find on a MIL-STD-1553B Databus Harness BCF/R/242/E/0442 Issue 1; 31/1/2002, (ASSC/110/2/204)

The following report details validation testing carried out on the Test Plan (Issue 1) and its techniques, as a result of which the Test Plan was revised to this Issue 2. The report also gives further practical details of testing with real hardware.

(j) Validation of ASSC "Test Plan for Faultfinding in Installed Def Stan 00-18 (part 2) Bus Networks". (ASSC/110/2/191 – Draft 1) (June 2003)

4 Definition of Terms

- a.c.: alternating current.
- BIT: Built In Test.
- d.c.: direct current.
- In the loop: within the transmission path between two stubs involved in a test.
- kHz: thousands of Hertz.
- LRI: Line Replaceable Item.
- LRU: Line Replaceable Unit.
- Short in loop: implies a short in either one of the two stubs or bus couplers involved in the test or in the bus.
- Short in stub outside loop: implies a short in a stub other than the two stubs involved in the test.
- Terminal: an LRI or LRU connected to a stub.
- Terminator: Bus Terminator a resistor, with a value equivalent to the line characteristic impedance Z_o, connected across the two line conductors to terminate the main bus cable.
- TDR: Time Domain Reflectometer.
- The loop: the transmission path between two stubs involved in a test
- Vpp: volts peak-to-peak.
- Z_o: characteristic impedance.

5 Requirements for Testing

5.1 Power Down

All electrical power in the aircraft shall be shut down before the tests outlined herein are performed. Test equipment shall be isolated from the aircraft and shall not be mains powered.

5.2 CAUTION

All relevant safety regulations pertaining to work on aircraft must be complied with. Nothing in this test plan shall be taken as countermanding such regulations.

6 Failure Modes

Network failure modes fall into three broad categories:

- Permanent faults (e.g. terminal always failing to respond)
- Intermittent faults (e.g. terminal sometimes failing to respond)
- Occasional bursts of errors (classically caused by short circuit between signal conductor and shield)

Possible causes of network failure include:

- Short circuits between signal conductors in stubs or bus
- Open circuit signal conductors in stubs or bus
- Cross-overs of signal conductors in stubs or bus
- Short circuits between either of the signal conductors and the shield in stubs or bus
- Open circuit, short circuit or incorrect value termination resistors
- Coupler box faults e.g. transformer or isolation resistor faults
- Terminal dummy load resistor used for terminator or vice-versa
- Incorrectly performed modifications or repairs to the network

7 Testing Strategy

This section summarises principles and issues that should be considered when fault finding in DEF-STAN 00-18 (Part 2) bus network systems.

7.1 “Footprinting”

An insertion loss ‘footprint’ for each aircraft, as discussed in 8.3.2 below, provides a valuable aid to detecting changes in bus performance and hence detecting and locating faults.

7.2 Use of Built in Test (BIT)

The selection from, and detailed performance of, the tests set out in Section 8 will depend on the system behaviour observed. Before commencing bus testing the behaviour of the overall system (e.g. terminal no responses, detection of message errors etc.) should be characterised and reviewed using BIT facilities in order to try and identify those areas of the system most likely to be at fault.

7.3 Minimum Physical Disturbance

An objective should be to test with minimum physical disturbance to bus or terminal hardware by connecting to the network via available connectors wherever possible. This usually implies testing and fault finding from the stub to LRU/LRI connectors. Movements of cables or connectors should always be made with an awareness that intermittent faults could easily be made to disappear, only to reappear at a later point during service.

7.3.1 Replacement or Disconnection of LRUs and LRIs

It is normal procedure to replace LRUs and LRIs in attempting to clear faults, before resorting to bus network testing. However, full functional testing of the disturbed LRU/LRIs and other related system elements (e.g. other LRU/LRIs that the disturbed LRU/LRIs exchange messages with) will be required following replacement or re-connection. Such procedures are costly and time consuming, and lead to aircraft out of service for extended periods.

Hence replacement or disconnection of LRU/LRIs from the network should only be undertaken when essential to the faultfinding process. It is recommended that BIT be used to localise faults and allow as few LRU/LRIs as possible to be disturbed in order to limit the need for full functional testing.

7.3.2 Physical Interference with Bus Network

Physical interference with the bus network (e.g. de-mating and re-mating of connectors, severing and reconnecting of cables, replacement of couplers etc.) is also most undesirable because of the time taken, difficulty of access, need for skilled wiring personnel and risk of introducing unreliable connections or further faults. There is also a risk of reduced reliability introduced by cable splices.

Therefore primary objectives should be to perform investigations with minimal disconnection of LRU/LRIs and physical intervention only when essential for final fault location and rectification. This test plan has been formulated these objectives in mind.

7.4 Occasional Bursts of Errors

Occasional bursts of errors (indicated by BIT or bus analyser test equipment) are often caused by short circuits between a signal conductor and shield. Experience has shown that buses often continue to function in this condition, but with impaired immunity to interference.

7.5 Visual Inspection and Fault Provocation

Visual inspection of the bus hardware for damage should form an important part of the investigative procedure.

Mechanisms causing intermittent faults may sometimes be provoked for investigation by careful movement of cables or connectors.

7.6 Retest after repair

All system elements (both LRU/LRIs and bus network hardware) disturbed during testing shall be re-tested following repair.

Relevant bus network hardware shall be subjected to all the tests outlined in Section 8 and LRU/LRIs shall be subjected to full functional testing.

8 Test Procedures

8.1 Order of Testing

It is recommended that the a.c. Shield Isolation test set out in 8.2.1 should be performed first. This test only needs to be carried out once to check the entire main bus for shield isolation (It will detect shield shorts in the main bus, the two stubs (transformer or direct coupled) used for the test, and all direct coupled stubs. It is unlikely to detect faults in transformer coupled stubs out of the loop). Hence, in the event that the fault is a short to shield the amount of testing required is minimised by doing this test first.

The remaining tests may be performed in any order as appropriate to the problem under investigation.

8.2 Shield Isolation Tests

Two tests are required.

The a.c. Shield Isolation Test described in 8.2.1 is principally used to detect shorts between signal conductors and shield in stub or bus cables anywhere in the bus and in either of the two stubs in the loop. Note that, in the context of this test, “anywhere in the bus” will include direct coupled stubs in and out of the loop.

The d.c. Shield Isolation Test described in 8.2.2 is used to detect a short between signal conductor and shield in a transformer coupled stub under test.” (It is inappropriate for use on a direct coupled stub.)

8.2.1 a.c. Shield Isolation Test

8.2.1.1 Purpose

The purpose of this test is to detect a short between the shield and a signal conductor anywhere in the bus and in either of the two stubs in the loop.

8.2.1.2 Procedure

Note

This test should not be performed between couplers in the same multi-coupler box. When performed on loops including transformer coupled stubs, this test relies on a signal path provided by the inter-winding capacitance of the transformer(s). If this test if performed between stubs connected within the same multi-coupler box the capacitance between components associated with different stubs may be high enough to give misleading results. Hence a more remote stub should be chosen for either the transmitter or receiver connection.

Referring to Figure 1, short together the signal conductors at the LRU/LRI connector of an appropriate stub and using a calibrated, source inject a signal between the signal conductors and the shield. The following signal characteristics have been shown from experience to be appropriate:

- Rectangular pulse
- Pulse width 5μs
- Repetition rate 5000 per second

- Amplitude 16V peak

Short together the signal conductors at the LRU/LRI connector of another stub and observe the signal between the conductors and shield using an isolated measuring instrument.

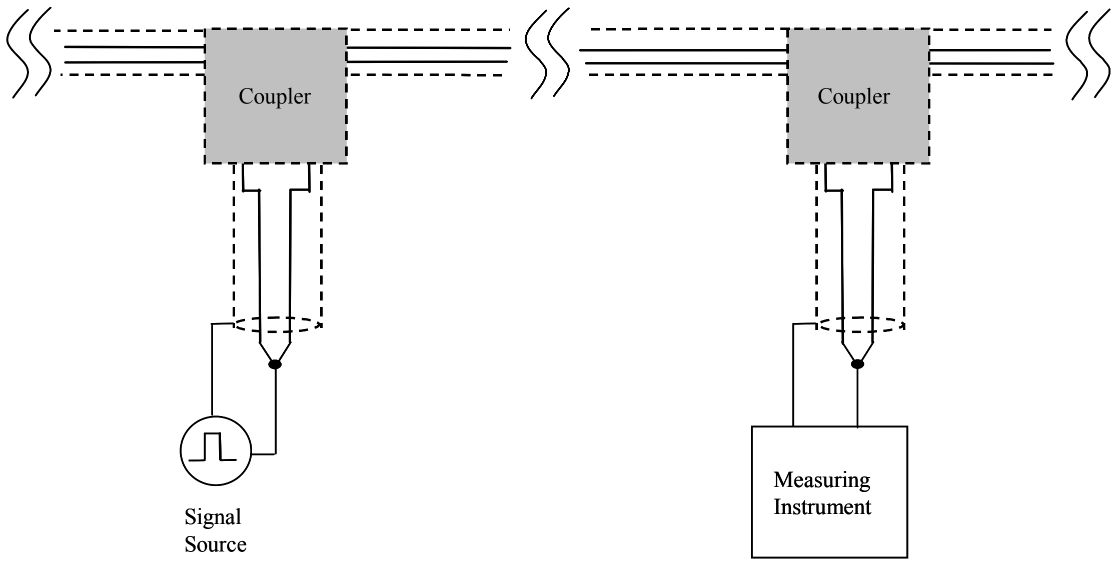


Figure 1: a.c. Shield Isolation Test Setup

8.2.1.3 Results

The received signal should have similar timing characteristics to the transmitted signal with amplitude depending on the coupler types, as in Table 1.

Signal Source Stub	Measuring Stub	Typical Received Amplitude*
Transformer Coupled	Transformer Coupled	4-200mV peak
Transformer Coupled	Direct Coupled	0.2-2V peak
Direct Coupled	Transformer Coupled	0.2-2V peak
Direct Coupled	Direct Coupled	>10V peak

Table 1: a.c. Shield Isolation Test - Received Signal Amplitude

* Note

The actual received amplitude is dependent upon coupling transformer interwinding capacitance. Since this is an uncontrolled parameter the figures given are for guidance only.

Failure to meet the criteria given in Table 1 most probably indicates a short between a signal conductor and shield which could be anywhere in the parts of the bus network as detailed in **Error! Reference source not found.**.

Although less likely, failure could also result from:

- an open circuit in both signal conductors in either of the two stubs used for the test
- an open circuit in both signal conductors in the bus between the stubs used for the test.

In either of these cases an insertion loss test as defined in Section 8.3 will provide an indication of the type of fault.

BIT would also provide evidence to support either of these diagnoses.

If this test indicates a shield to signal conductor short then, in the case of transformer coupled stubs, the test outlined in 8.2.2 should be performed to determine which stub, if any, the fault is located in.

8.2.2 d.c. Shield Isolation Test

8.2.2.1 Purpose

The purpose of this test is to detect a short between the shield and a signal conductor in a transformer coupled stub.

8.2.2.2 Procedure

This test should be applied to the each of the suspect stubs in turn.

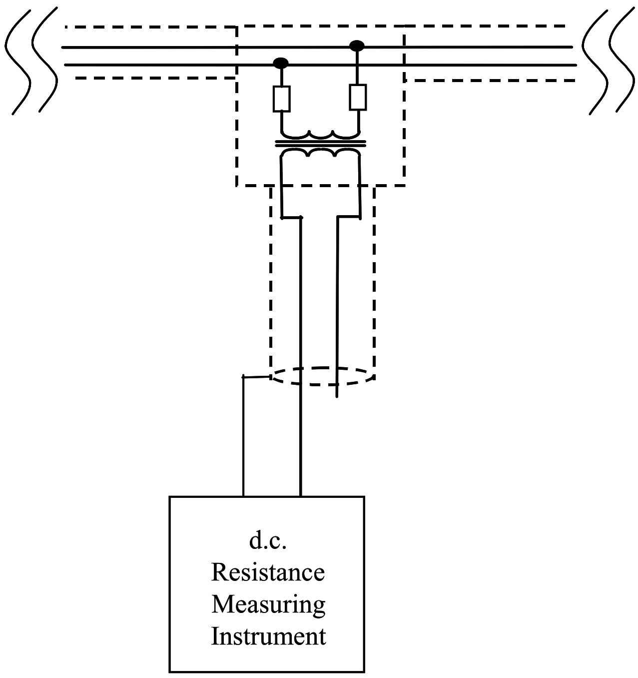


Figure 2: d.c. Shield Isolation Test Setup

Referring to Figure 2, measure the resistance between one of the signal conductors and the shield at the LRU/LRI connector of the suspect stub.

8.2.2.3 Results

The resistance should be greater than1MΩ.

.

8.3 Insertion Loss Tests

8.3.1 Purpose and Introduction

The purpose of these tests is to identify and isolate faults by measuring the insertion loss between two stubs. The selection of stubs for this test will depend upon observed system behaviour e.g. no responses from remote terminals, detection of message errors etc.

8.3.2 Bus Network ”Footprinting”

The Insertion Loss test is a powerful and versatile test. Insertion Loss figures to be expected in no-fault and specified fault conditions are given in the following sections, however, results do vary according to bus length and number of stubs. Quite small differences in insertion loss reading may give a significant clue to the fault present, but these differences can be smaller than the differences due to different bus configurations. It is therefore most helpful to have an insertion loss ‘footprint’ (a set of measurements of insertion loss from one defined stub to all other stubs, with no fault present) of the bus on each aircraft. If this exists, then small insertion loss differences can be detected. If a footprint does not exist, then it is desirable that a full set of measurements be made and a footprint logged in the aircraft maintenance file at an early opportunity.

With the availability of a footprint, insertion loss changes of less than 0.5 dB can easily be detected. It may be noted that a similar increase in all insertion loss readings indicates a change in the behaviour of the main bus or the one defined transmitter stub (e.g. increased impedance of an in-line connector or splice). An increase in just one measurement indicates a change in only the receiver stub.

Connection and results will vary according to whether transformer coupled stubs or direct coupled stubs are used for transmit/in and receive/out connection

8.3.3 Procedure

Insertion loss tests consist of injecting a signal at one stub and measuring the signal received at another stub. The insertion loss is the ratio of the received to transmitted amplitude expressed in dB.

If the signal source is to be connected to a transformer coupled stub, then it shall be connected as shown in Figure 3.

If the signal source is to be connected to a direct coupled stub, then it shall be connected as shown in Figure 4, using an adapter. Adaptor details are shown in Figure 5 (a spare transformer coupler box may be used for this purpose).

The measuring instrument shall be connected to a stub as shown in Figure 6 (Transformer Coupled Stub) or Figure 7 (Direct Coupled Stub) as appropriate.

Using a calibrated, balanced, isolated source, inject a signal between the signal conductors of an appropriate stub at its LRU/LRI connector.

Experience has shown that the following signal parameters are appropriate:

- Squarewave
- Amplitude 12Vpp
- Frequency 200kHz

Using an isolated measuring instrument measure the signal level received at another appropriate stub and compute the ratio of transmitted to received signal amplitude in dB.

8.3.4 Results

Error! Reference source not found. (Output via a Transformer Coupled Stub) and **Error! Reference source not found.** (Output via a Direct Coupled Stub) list the nominal values of insertion loss for no fault and various fault conditions. See the notes following the tables for important detail on interpretation of results.

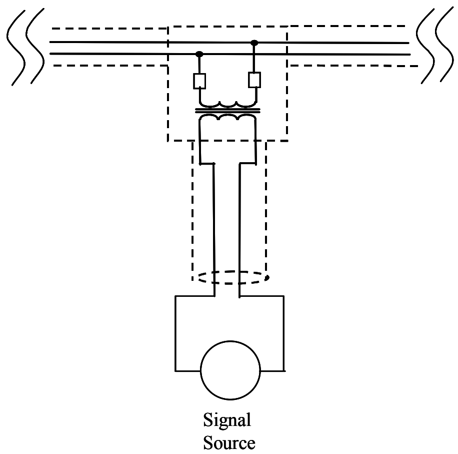


Figure 3: Insertion Loss Input Connection to Transformer Coupled Stub

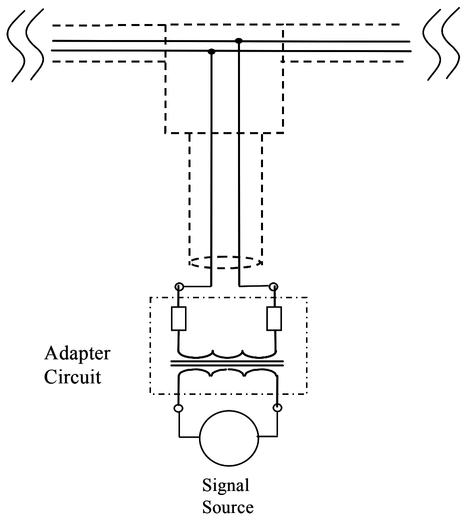


Figure 4: Insertion Loss Input Connection to Direct Coupled Stub via Adaptor

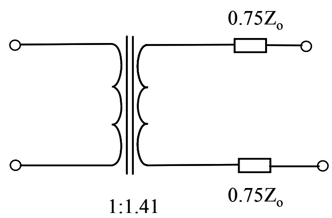


Figure 5: Adaptor Circuit for Insertion Loss Test with Input via Direct Coupled Stub (as in Figure 4 above)

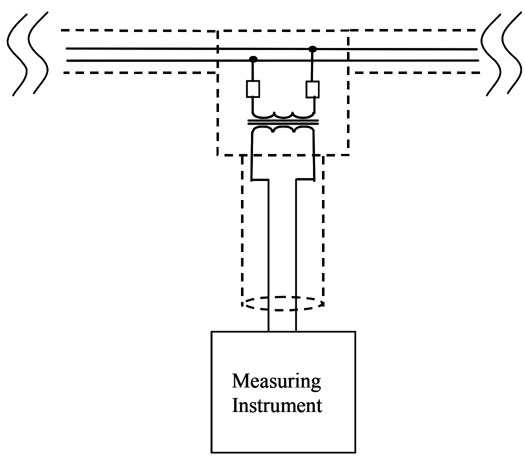


Figure 6: Insertion Loss Output Connection to Transformer Coupled Stub

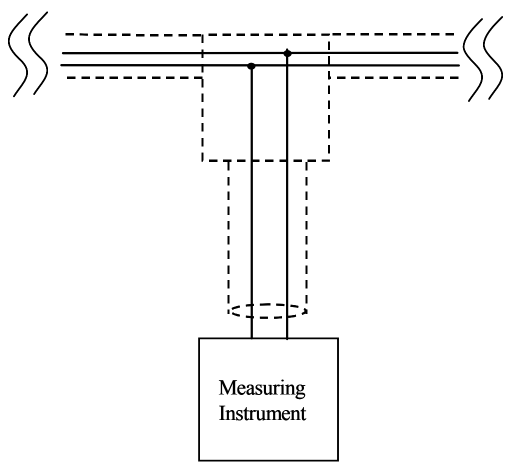


Figure 7: Insertion Loss Output Connection to Direct Coupled Stub

Receiving Stub Transformer Coupled	
Ratio Received to Transmitted Signal Amplitudes (dB)	**Possible Fault Conditions to give rise to the Insertion Loss result**
0 Notes: **(Error! Reference source not found.)(Error! Reference source not found.)(Error! Reference source not found.)(Error! Reference source not found.)(Error! Reference source not found.)**	·Two bus terminators open circuit ·Two terminators high resistance (e.g. terminal dummy loads used by mistake) ·Two bus open circuits – one each side of the loop
-8 Notes: **(Error! Reference source not found.)(Error! Reference source not found.)(Error! Reference source not found.)(Error! Reference source not found.)(Error! Reference source not found.)**	·One bus terminator open circuit ·Bus wire to one terminator broken ·One high resistance terminator (e.g. terminal dummy load used by mistake) ·Open circuit anywhere in the bus outside the loop
-12 Notes: **(Error! Reference source not found.)(Error! Reference source not found.)(Error! Reference source not found.)**	·**NO FAULT**
-13 Notes: **(Error! Reference source not found.)(Error! Reference source not found.)(Error! Reference source not found.)**	·Terminator used as terminal dummy load on a transformer coupled stub by mistake
-14 Notes: **(Error! Reference source not found.)(Error! Reference source not found.)(Error! Reference source not found.)**	·Short in transformer coupled stub outside loop ·Short in a direct coupled terminal outside the loop and on the terminal side of the isolation resistors
-15 Notes: **(Error! Reference source not found.)(Error! Reference source not found.)(Error! Reference source not found.)**	·Terminator used as terminal dummy load on a direct coupled stub by mistake

<-25 Notes: **(Error! Reference source not found.)(Error! Reference source not found.)(Error! Reference source not found.)(Error! Reference source not found.)**	• Short anywhere in the bus or in stubs under test • Open circuit in loop • Short in direct coupled stub outside loop and outboard of isolation resistors

Table 2: Insertion Loss Versus Probable Fault Conditions with Receiving Stub Transformer Coupled

Receiving Stub Direct Coupled	
Ratio Received to Transmitted Signal Amplitudes (dB)	**Possible Fault Conditions to give rise to the Insertion Loss result**
+3 Notes: **(Error! Reference source not found.)(Error! Reference source not found.)(Error! Reference source not found.)(Error! Reference source not found.)(Error! Reference source not found.)**	• Two bus terminators open circuit • Two terminators high resistance (e.g. terminal dummy loads used by mistake) • Two bus open circuits – one each side of the loop
-5 Notes: **(Error! Reference source not found.)(Error! Reference source not found.)(Error! Reference source not found.)(Error! Reference source not found.)(Error! Reference source not found.)**	• One bus terminator open circuit • Bus wire to terminator broken • High resistance terminator (e.g. terminal dummy load used by mistake) • Open circuit anywhere in the bus outside the loop
-9 Notes: **(Error! Reference source not found.)(Error! Reference source not found.)(Error! Reference source not found.)**	• **NO FAULT**
-10 Notes: **(Error! Reference source not found.)(Error! Reference source not found.)(Error! Reference source not found.)**	• Terminator used as terminal dummy load on a transformer coupled stub by mistake
-11 Notes: **(Error! Reference source not found.)(Error! Reference source not found.)(Error! Reference source not found.)**	• Short in transformer coupled stub outside loop. • Short in a direct coupled terminal outside the loop and on the terminal side of the isolation resistors

-12 Notes: (**Error! Reference source not found.**)(**Error! Reference source not found.**)(**Error! Reference source not found.**)	• Terminator used as terminal dummy load on a direct coupled stub by mistake
<-25 Notes: (**Error! Reference source not found.**)(**Error! Reference source not found.**)(**Error! Reference source not found.**)(**Error! Reference source not found.**)	• Short anywhere in the bus or in stubs under test • Open circuit in loop • Short in direct coupled stub outside loop and outboard of isolation resistors

Table 3: **Insertion Loss Versus Probable Fault Conditions with Receiving Stub Direct Coupled**

Notes to Insertion Loss Tables.

The dB insertion loss figures given in the table above are theoretical first order calculations based on a short bus with a small number of stubs. In practice the insertion loss can vary due to a variety of factors. Related Document **Error! Reference source not found.** on p1 gives further details. Some of the factors are listed below:

1. Even with a fault-free bus, imperfections in the transmission line characteristics will increase insertion loss readings according to the positions of the transmitting and receiving stubs (see note 2 for guidance on the amount of additional attenuation).

2. Attenuation in the bus cable will increase insertion loss (this should be less than 4.92dB/100m. e.g. a bus length of 20m between the stubs used in the test will introduce up to 1 dB of additional attenuation).

3. Tolerances on transformer coupler unit component parameters (up to ±3.3dB theoretical worst case).

4. When one, or more especially, when both bus terminating resistors are missing or open circuit, the signal may become distorted resulting in significant deviations in the measured voltages and insertion loss calculations (the validation exercise suggests that differences may be up to ±2.5dB).

5. When one, or more especially, when both bus terminating resistors are missing, then the effect of stub loads becomes prominent and must be considered when estimating the likely insertion loss.

6. When a signal conductor open circuit is near to either end of the bus, then insertion loss figure will be low (<-50dB). However, when a signal conductor open circuit is near to the centre of the bus, then the insertion loss figure may be as high as <-25dB. This appears to be the result of propagation of transient spikes at the transmitted signal pulse edges through signal conductor to screen capacitance. The effective capacitance is greatest when the open circuit is near to the centre of the bus.

The potential effects of the above factors on insertion loss make “Footprinting”, as discussed in 8.3.2 above a potentially very valuable excersise.

8.4 Phase Test

8.4.1.1 Purpose

The purpose of this test is to detect phase inversion faults. Such faults can only occur in new bus assemblies, or those modified or repaired immediately before the advent of the faulty behaviour. Clearly where modifications or repairs have been carried out immediately before the onset of problems the details of these should give strong pointers to probable fault locations.

8.4.1.2 Procedure

Using the same test set-ups as for Insertion loss testing and as shown in Figure 3 to Figure 7 proceed as follows.

Using a calibrated, balanced, isolated source inject a signal between the signal conductors of an appropriate stub at its LRU/LRI connector.

Experience has shown that the following signal parameters are appropriate:

- Rectangular pulse
- Pulse width 5μs
- Repetition rate 5000 per second
- Amplitude 16V peak

8.4.1.3 Results

Compare the phase of the signals at the problem stub with that at a good stub. These signals should have the same polarity as the transmitted signal. In cases where the receiving stub is transformer coupled the received amplitude should be 4.0±0.4V peak. If the receiving stub is direct coupled the received amplitude should be 5.6±0.6V peak.

Different polarity indicates phase reversal, this could result from switched signal conductors in either stub or in the bus.

If the received amplitude is outside the above tolerance this may be indicative of one of a number of faults and should be investigated using the insertion loss tests set out in 8.3 above.

8.5 Final Fault Location

This section provides guidance on methods of determining the physical location of the various types of faults whose identification is described in Sections 8.2 to 8.4 above.

8.5.1 Overview

In attempting to locate and rectify bus network faults it is often useful to consider the recent history of the aircraft. Bus and stub cables are relatively fragile and may suffer inadvertent damage during maintenance and repair operations. Hence reviewing any recent work carried out on the aircraft may provide valuable clues to the location of bus network faults.

In the majority of platforms the main bus and stubs do not have production break connectors and terminators are either spliced in or integrated into coupler units. Where such connectors are used they are often inaccessible. The only points guaranteed to be reasonably accessible and removable are the stub to LRU/LRI connectors.

In the rare cases where buses or stubs pass through bulkhead connectors it may be possible, if accessibility permits, to isolate sections of the network as an aid to fault location. However, the implications of disconnecting and re-mating such connectors should be carefully considered in terms of the requirements for functional testing of the effected system elements that will be essential following re-connection.

In many cases involving suspected cable faults, fault location should (if accessibility permits) start with visual inspection of the bus or stub cable, since faults are often caused by damage to cables.

If a cable fault cannot be precisely located but its general position (e.g. within a stub or part of the bus) has been identified with confidence, the suspect length of cable may be replaced by splicing in new cable.

In addition to cables, faults may also occur in coupler boxes, terminators, or connectors. Furthermore, it is important to note that stub related faults may occur inside LRU/LRIs.

Faults may include:

- Chafed, trapped, or kinked cables
- Broken wires in connectors and couplers
- Failed solder joints in connectors and couplers
- Dirty, displaced or damaged contacts in connectors
- Wrong value bus terminators (e.g. terminal dummy loads used by mistake)
- Wrong value terminal dummy load (e.g. bus terminator used by mistake)
- Wrong value or faulty coupler box isolation resistors
- Partially mated connectors

In-line couplers are widely used and are often difficult to access and replace. Hence it is important to have a high degree of confidence in the fault location before replacing couplers.

8.5.2 Open Circuit Bus Terminators or Broken Bus Wire to Terminator

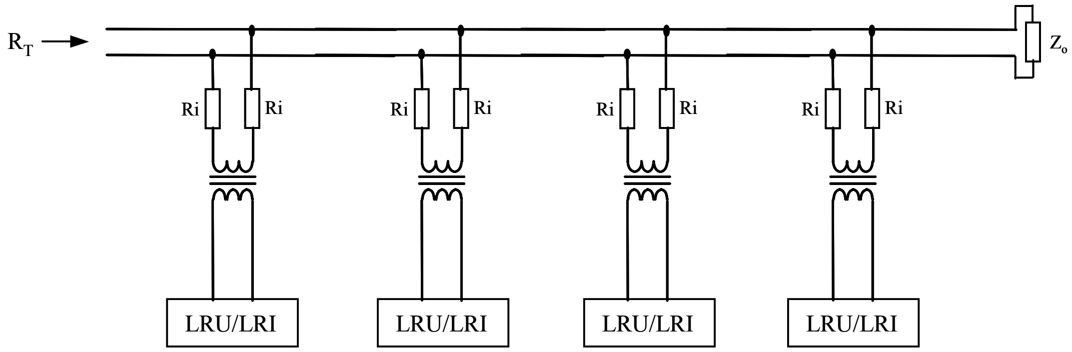
The following procedure is recommended:

1. If possible locate and remove one of the bus terminators, inspect it and measure its resistance for comparison with the specified value. If fault free, either:

2. Locate and remove the other bus terminator (if possible), inspect it and measure its resistance for comparison with the specified value.

or

3. Measure the d.c. resistance between the signal conductors at the bus terminator removed in 1. This should be in accordance with the formula in Figure 8 relating the number of transformer coupled stubs, isolation resistor values and terminator resistor values to the measured resistance.



$R_i = 0.75\ Z_0$

Neglecting coupling transformer winding resistance (1Ω approx) the resistance of each stub is approximately 2 x 0.75 Z_0 = 1.5 Z_0.

If number of transformer coupled stubs = N

$R_T = Z_0$ in parallel with $1.5Z_0/N$.

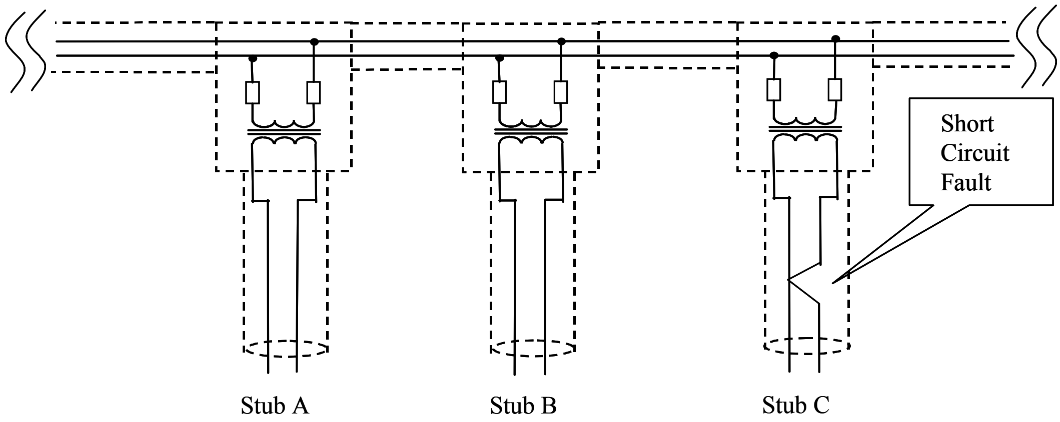
$= Z_0 \times 1.5Z_0/N \div [Z_0 + 1.5\ Z_0/N]$

$= 1.5Z_0 \div [1.5 + N]$

Figure 8: Resistance Measured from Terminator

8.5.3 Short Between Signal Conductors in Stub

This type of fault may be located to one stub using the insertion loss test outlined in 8.3. Figure 9 shows the principle.



Insertion loss between Stub A and Stub B = -14dB

Insertion loss between Stub A and Stub C = <-25dB

Fault is short in Stub C

Figure 9: Location of Short Circuit Signal Conductors in Stub Based on the Results of Insertion Loss Tests

Stubs should be kept short by design. Hence once a fault has been isolated to a given stub visual inspection may be sufficient to locate it.

If visual inspection of the stub cable and stub to LRU/LRI connectors reveals no damage then following procedure may be adopted:

1. Disconnect the stub to LRU/LRI connector.
2. Measure resistance into LRU/LRI to detect a possible short inside LRU/LRI (note that the windings of LRU/LRI input transformers typically have a resistance of about 1Ω hence a sensitive instrument is required to distinguish between the winding resistance and a short).
3. Measure the resistance into the stub from LRU/LRI connector to detect a possible short in the stub connector, stub cable or coupler box (note that the stub windings of coupler transformers typically have a resistance of about 1Ω).
4. If a short is found in **Error! Reference source not found.** then, given a sufficient level of confidence, the following steps may be performed to determine the exact location of the fault.
5. Open the LRU/LRI connector and inspect for internal faults.
6. If no fault is found at **Error! Reference source not found.** then sever the stub cable near the coupler box and perform the following steps.
7. Measure the resistance between the signal conductors entering the coupler box, to detect a possible short inside the coupler box (note that the stub windings of coupler transformers typically have a resistance of about 1Ω).

8. If no fault found in **Error! Reference source not found.** then splice in new cable between coupler box and LRU/LRI.

8.5.4 Short Between Signal Conductors in Bus

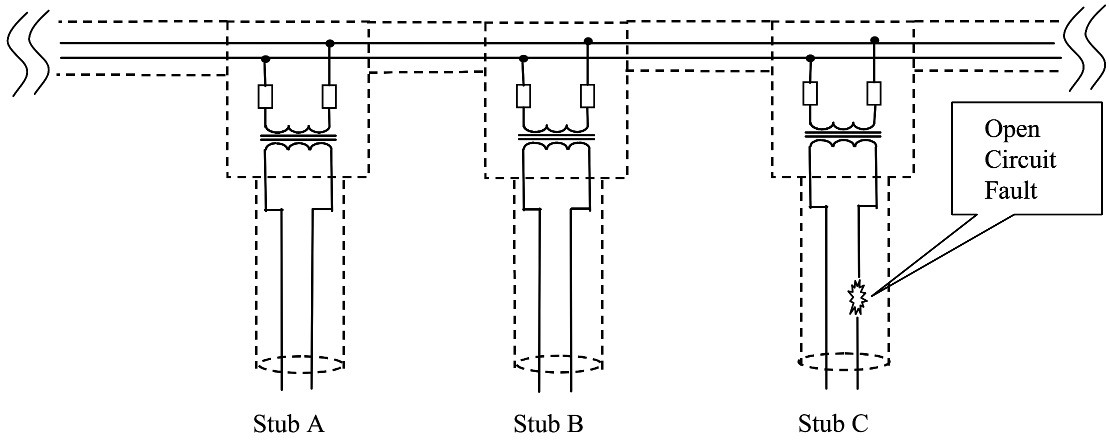
This type of fault causes the entire bus network to be shutdown and therefore neither BIT nor insertion loss tests are able to provide help in fault location. However, the fault may be located either using a TDR or by resistance measurement (see **Error! Reference source not found. Error! Reference source not found.** below.)

When using a TDR, locate and remove a bus terminator and connect the TDR between the bus signal conductors. It may be possible to locate the fault by identifying the reflection from the bus short and computing the distance from the end of the bus from the delay between the transmitted pulse and the reflection, given the necessary information on cable length etc. However, reflections from the impedance mismatches imposed by the stubs may make identification of the reflection from the fault difficult to identify.

In the absence of a TDR (or difficulty with its utilisation) it may be possible to locate the approximate position of a bus short using resistance ratio measurements as follows. Remove both terminators and measure the resistance between the signal conductors from each end of the bus in turn using a precision instrument. Given the total length of the bus, the position of the short may be computed from the ratio of the two resistance values measured.

An alternative resistance measurement method, sometimes described as the Binary Split Technique, may be used - given sufficient confidence in the diagnoses. The bus is severed near its mid point (making sure that the severed ends of the signal conductors and shield are not in contact) and the resistance between the signal conductors is measured in each half of the bus. The half with the short should exhibit low resistance and that with no fault higher resistance (in accordance with the formula at Figure 8). The faulty half of the bus may then be severed near its mid point and resistance measurements repeated to determine which part has the fault. This process is repeated until the fault is sufficiently isolated to permit rectification by cable or coupler replacement or other means as appropriate. It is important to make careful notes of where the bus has been severed to permit reconnection. This method will require extensive testing of both bus network and LRU/LRIs following repair in order to verify correct performance and to ensure no new faults have been introduced.

8.5.5 Open Circuit Signal Conductors in Stub



Insertion loss between Stub A and Stub B = -12dB

Insertion loss between Stub A and Stub C = <-25dB

Fault is open circuit in Stub C

This type of fault may be located to one stub using the insertion loss test outlined in 8.3.

Figure 10 shows the principle.

Figure 10: Location of Open Circuit Signal Conductor in Stub Based on the Results of Insertion Loss Tests

Stubs should be kept short by design. Hence once a fault has been isolated to a given stub visual inspection may be sufficient to locate it.

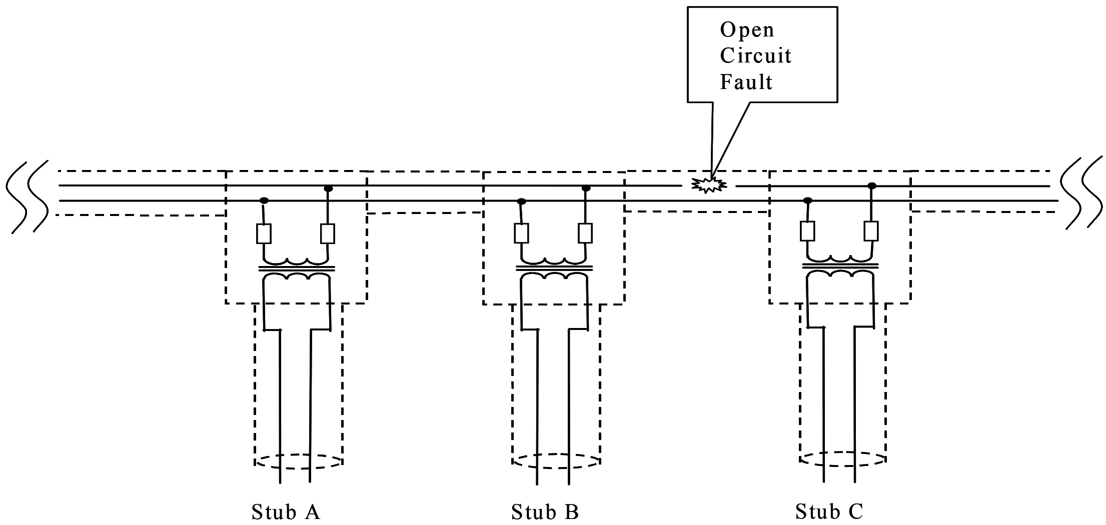
If visual inspection of the stub cable and LRU/LRI connector reveals no damage then the following procedure may be adopted:

1. Disconnect the stub to LRU/LRI connector.
2. Measure resistance into LRU/LRI to detect a possible open circuit inside the LRU/LRI (note that the windings of LRU/LRI input transformers typically have a resistance of about 1Ω).
3. Measure the resistance into the stub from LRU/LRI connector to detect a possible open circuit in the stub connector, stub cable or coupler box (note that the stub windings of coupler transformers typically have a resistance of about 1Ω).
4. If an open circuit is found in **Error! Reference source not found.** then, given a sufficient level of confidence, the following steps may be performed to determine the exact location of the fault.
5. Open the LRU/LRI connector and inspect for internal faults.
6. If no fault is found at **Error! Reference source not found.** then sever the stub cable near the coupler box and perform the following steps.
7. Measure the resistance between the signal conductors entering the coupler box, to detect a possible open circuit inside the coupler box (note that the stub windings of coupler transformers typically have a resistance of about 1Ω).

8. If no fault found in **Error! Reference source not found.** then splice in new cable between coupler box and LRU/LRI.

8.5.6 Open Circuit Signal Conductor in Bus

This type of fault may be located to between two stubs using the insertion loss test outlined in 8.3. Figure 11 shows the principle.



Insertion loss between Stub A and Stub B = -8dB

Insertion loss between Stub A and Stub C = <-25dB

Fault is open circuit in main bus between Stubs B and C

Figure 11: Location of Open Circuit Signal Conductor in Bus to Between Two Stubs Based on the Results of Insertion Loss Tests

In many cases determining the location of a bus open circuit to between two adjacent stubs will be sufficient to allow its physical position to be determined. In cases where the two stubs on either side of the fault are connected by an extended length of bus, making location difficult, it may be possible to determine the physical position of this type of fault by using a TDR. (See **Error! Reference source not found. Error! Reference source not found.** below.)

To use the TDR locate and remove one bus terminator and connect the TDR between the signal conductors. It may then be possible to locate the fault by identifying the reflection from the bus open circuit and computing the distance from the end of the bus from the delay between the transmitted pulse and the reflection. However, reflections from the impedance mismatches imposed by the stubs may make identification of the reflection from the fault difficult to identify.

In the absence of a TDR (or difficulty with its utilisation) the simplest solution may be to sever the damaged bus cable adjacent to each of the couplers (stub couplers B and C in Figure 11) and splice in a new length of cable.

8.5.7 Short between Signal Conductors and Shield in Stub

Stubs should be kept short by design. Hence once a fault has been isolated to a given stub (as described in 8.2 above) visual inspection may be sufficient to locate it.

If visual inspection of the stub cable and stub to LRU/LRI connectors reveals no damage then following procedure may be adopted:

1. Disconnect the stub to LRU/LRI connector.
2. Measure resistance between the signal contacts and connector shell looking into LRU/LRI to detect a possible short inside LRU/LRI.
3. Measure the resistance between the signal contacts and connector shell looking into the stub to detect a possible short in the stub connector, stub cable or coupler box.
4. If a short is found in **Error! Reference source not found.** then, given a sufficient level of confidence, the following steps may be performed to determine the exact location of the fault.
5. Open the LRU/LRI connector and inspect for internal faults.
6. If no fault is found at **Error! Reference source not found.** then sever the stub cable near the coupler box and perform the following steps.
7. Measure the resistance between the signal conductors and shield entering the coupler box, to detect a possible short inside the coupler box.
8. If no fault found in **Error! Reference source not found.** then splice in new cable between coupler box and LRU/LRI.

8.5.8 Short between Signal Conductors and Shield in Bus

It may be possible to locate the approximate position of a short between a signal conductor and the shield in a bus using resistance ratio measurements as follows. Remove both terminators and measure the resistance between each of the signal conductors and shield from each end of the bus in turn, using a precision instrument. Given the total length of the bus, the position of the short may be computed from the ratio of the two resistance values measured.

Alternatively a TDR may be connected between the shield and each signal conductor in turn to try and locate the position of the fault (see **Error! Reference source not found. Error! Reference source not found.** below.)

Alternatively the Binary Split Technique, may be used - given sufficient confidence in the diagnoses. The bus is severed near its mid point (making sure that the severed ends of the signal conductors and shield are not in contact) and the resistance between the signal conductors and shield is measured in each half of the bus. The half with the short should exhibit low resistance and that with no fault a resistance greater than 1MΩ. The faulty half of the bus may then be severed near its mid point and resistance measurements repeated to determine which part has the fault. This process is repeated until the fault is sufficiently isolated to permit rectification by cable or coupler replacement or other means as appropriate. It is important to make careful notes of where the bus has been severed to permit reconnection. This method will require extensive testing of both bus network and LRU/LRIs following repair in order to verify correct performance and to ensure no new faults have been introduced.

8.5.9 Notes on TDR Testing

Experience has shown that in practice reflections from the impedance mismatches imposed by stubs often makes reflections from bus faults difficult to identify.

3 Related Documents **Error! Reference source not found.** sets out the results of an evaluation of the use of a TDR to determine and locate bus faults. In summary it finds that the TDR has severe limitations when used on a branched harness with passive electrical

components such as a Def Stan 00-18 (Part 2) system. However, the TDR used detected all fault types on the main bus of a small network with the exception of a crossover fault. A significant drawback being the need to have access to break into the main bus. The utility of TDR testing to identify and locate stub faults was found to be very limited.

8.6 Re-test Following Rectification

It is essential that all parts of the bus network that have been subjected to physical disturbance during investigation and rectification work be subjected to all the tests set out in Section 8 above in order to ensure correct performance before the aircraft is returned to service.