

Automated Fault Isolation of Intermittent Wiring/Conductive Path Systems Inside Weapons Replaceable Assemblies

Oliviu Muja

Naval Air Systems Command

David Lamper

Eclypse International Corporation

ABSTRACT

Automated Fault Isolation of Intermittent Wiring/Conductive Path Systems Inside Weapons Replaceable Assemblies

Wiring/conductive path faults inside Weapon Replaceable Assemblies (WRAs) that result in No Fault Found (NFF) or intermittent diagnosis are estimated to cost the DoD over \$2B annually. To date there is no logistically supportable, standardized capability to reduce this annual cost. This report covers the development of this capability and its subsequent testing and fielding as a means to reduce this component repair costs. This new capability is called the Automated Wiring Test Set (AWTS) intermittent testing capability.

To test the new capability, the F/A-18 APG-73 Radar Receiver (RR) chassis was selected due to its high repair cost and its #1 ranking as an avionics mission degrader for this type aircraft.

The new capability can automatically test over 3400 conductive paths inside the chosen RR chassis using customized interface cables and replacement dummy circuit card boards for the real boards. All conductive paths can be queried and analyzed in less than a minute for static tests and less than 30 minutes for dynamic (vibration) tests. The new capability can test for opens, shorts, high impedance faults and resistors, capacitors and inductors faults. The new capability will enable the I-level and D-level technicians to quickly diagnose latent wiring faults.

The end result of applying this new capability showed that 93% of all RR chassis tested had latent wiring faults; only one RR chassis had no latent wiring faults. Of the wiring faults identified, 74% were diagnosed using static tests and an additional 26% were diagnosed during dynamic testing. The 26% wiring faults revealed during dynamic testing directly contribute to the NFF / intermittent DoD annual costs.

The new capability will augment the existing Consolidated Automated Support System (CASS) to eliminate latent wiring/conductive faults; CASS cannot and was not designed to diagnose wiring/conductive path faults. This new capability is scalable and adaptable to other avionic WRAs.

CITATION: Muja, O. and Lamper, D., "Automated Fault Isolation of Intermittent Wiring/Conductive Path Systems Inside Weapons Replaceable Assemblies," *SAE Int. J. Aerosp.* 5(2):2012, doi:10.4271/2012-01-2241.

INTRODUCTION

The F/A-18 Radar Receiver (part number 3525026-110) has had a long history of failures associated with the weapons replaceable assembly (WRA) which fails frequently, or after a short operational time since previous repair. Screening Logistics and Navy Supply data for this component identified 90 serial numbers (S/N) which had failed at least seven times within two years. There were 24 S/N with two or three Beyond Capability of Maintenance (BCM) / repair actions within the same two years, which indicates that even the depot repair facilities have difficulty troubleshooting and repairing the failed radar receivers. Due to its poor reliability,

this component has been designated a high interest item with special team focus by the NAVICP Integrated Weapon Support Team. There have been obsolescence reviews and engineering analyses on this system, but no attempts at redesign have been pursued. The APG-73 Radar Receiver (RR) is employed on various FA-18s A thru F models. It is a pivotal part of the radar system and is the most troublesome to maintain between the three types of receivers on the F/A-18A-F model aircraft. This legacy radar system and WRA will be in use until 2032 (current estimated retirement date). This WRA is required to be installed for safe flight operations and is regarded as a mission critical component. The APG-73 RR has been chosen as the pilot project to implement an

improved sustainment methodology using modern test capabilities which are already being fielded to regional maintenance centers. The APG-73 radar receiver was chosen for the following reasons:

- Recommended by CNAF, F/A-18 and Avionics Class Desks
- Number one downing avionics component for F/A-18: 2131 removals per year (averaged over the last 5 years)
- MFHBF across all F/A-18 TMS is 422 hours (averaged over last 5 years for all T/M/S)
- High cannibalization rate: 856 per year (for 587 total installs)
- High Net Repair Price: \$238,816 (since FY07 to FY11 it has increased more than 400%, from \$24,952 to \$238,816, with an average of \$158,537 during FY09-11).
- High AVDLR+AFM costs: > \$10M per year.
- 90 S/Ns with more than 7 failures within two years
- 24 S/Ns with two or three repeat BCMs within two years
- Complexity - more than 3400 conductive paths / test-points

PMA-265, the FA-18 program office, has requested development of a Test Program Set (TPS) to address this issue. It believes that many of the Radar Receiver Chassis problems are intermittent in nature and manifest while in flight. NAVAIR 4.4.5.3 / 6.7.1.3 in collaboration with Eclipse International (Eclipse) have developed the TPS for the Radar Receiver Chassis using the Automatic Wire Test Set (AWTS) hardware. During this report the chassis is referred to as the WRA with the SRA / circuit cards removed, such that only the metal frame and wiring remain in with the intent of increasing the probability of identifying intermittent faults. NAVAIR has evaluated the feasibility of using this TPS in a typical aircraft vibration environment to identify and locate intermittent wiring faults.

The Wiring Systems Branch has a proven capability with innovative designs and AWTS work, as it was awarded Avionics Component Improvement Program (AvCIP) funding to develop avionics WRA chassis wiring testing capability during FY 11. This effort was endorsed by the Common Avionics Program Office (PMA-209), CNAF Common Avionics and CNAF Avionics FA-18 Class Desk, as well as the PMA-265 the FA-18 Program Office which is responsible for the APG-73 Radar Receiver.

The Automated Wire Test Set (AWTS) suite of equipment was chosen as the program test equipment because it was recently fielded to every I-Level unit in the Navy, Marine Corps and Air Force and has an established logistics support, therefore; no additional support equipment to the Fleet inventory is required.

This specific effort was a collaboration between the NAVAIR Wiring Systems Team, uniformed end users and

Eclipse. The NAVAIR members developed the concept, and provided the direction, requirements in coordination with end-users. The team also performed the verification and validation effort, the laboratory testing and the operational testing along with the fielding, end user training, data analysis and program management. Eclipse was contracted to design and build the TPS, which includes the interface device and Test Adapter Cables (TACs) and the testing software to enable testing the Unit Under Test (UUT) which is the Radar Receiver. Uniformed Fleet end users at various squadrons, Fleet Support Team (FST) engineers and logisticians enabled the effort by providing access to the chassis and by performing the repairs once fault isolated. They also provided valuable inputs which shaped the final design and fielded capability. Their support and participation in this effort was paramount and pivotal.

The completed TPS design selected (TPS: 992-100-00001-01) includes interfaces test adapter cards. These adapter cards closely resemble the original Shop Replicable Assembly (SRA) in size, mounting hardware, and electrical mating, and interface cables that connected to the typical AWTS. Over 70% of the SRA connectors in the RR chassis are custom connectors. The adapter cards also include circuit cards for multiplexing the conductive paths.

The interface between the RR chassis and the AWTS is routed through the same external WRA connectors on the face of the box which are used by the aircraft side. The RR chassis has over 3000 conductive paths with a wiring architecture which includes primarily printed flex cable harnesses and multilayered motherboards.

Testing was divided in two stages, static and dynamic (under vibration). Static testing takes just under one minute and tests every conductive path for proper routing, opens and shorts, as well as passive electronic component (resistor, capacitor) testing. Dynamic testing takes approximately 30 minutes due to increased dwell time on every test circuit as it is tested 100 times, and the test cycle is run five sequential times. The intent of the vibration testing is to identify intermittent failures, while the intent of the static test is to identify static faults. The amplitude of the vibration profile was selected at only 1/8th that required for the qualification of this WRA. The frequency profile of the vibration testing was the same as the initial qualification testing as per "F/A-18 Radar Set - WRA Screening Requirements" performed by Hughes; report # WS32008-223-e. The report is on file with the author of this technical report. The validation and operational testing effort included:

- Software and TAC interface verification which was completed at NAS Miramar, MAL-11 Avionics Shop
- Software and TAC interface verification at NAS North Island FST CASS Test facility in June 2011
- Vibration testing was conducted at NAS Patuxent River, Power and Propulsion, Bldg 1461 in July, September, and October 2011



Documents

Document Sharing Hub

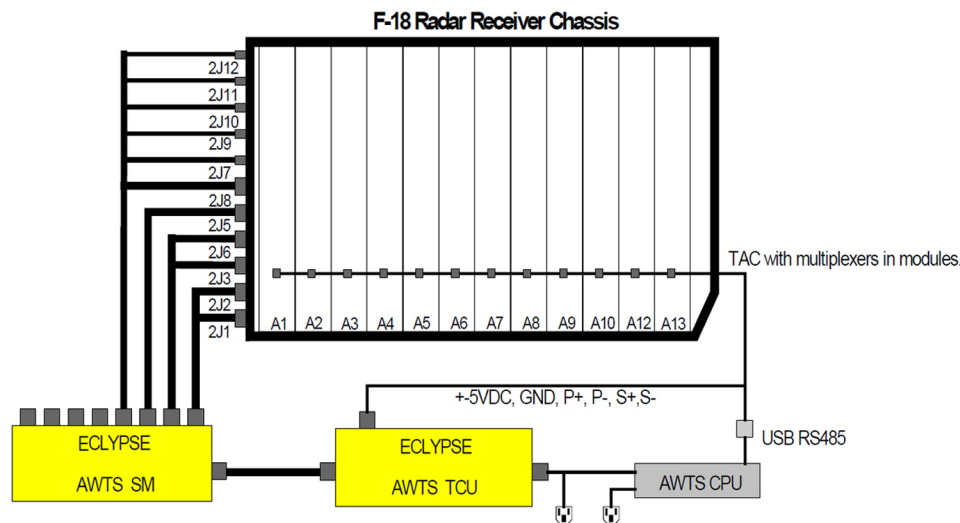


Figure 1. TAC Multiplexer Test Setup Diagram

• Operational testing was performed at NAS Oceana at the FRC Mid-Atlantic and NAS Lemoore Avionics Repair Facility in August, September, and October 2011.

METHODOLOGY

APG-73 RR testing and data collection with analysis requires AWTS, TACs, and test software. AWTS is standard-issue Navy and Marine equipment (also compatible with the Air Force issued AWTS) while the TACs and test software were specifically developed by Eclipse in collaboration with the NAVAIR Wiring Team, using a three phased approach; phase 1 - test strategy development, phase 2 - material procurement, and phase 3 - development continuation, fabrication of the test interface including multiplexer modules, TPS validation, and testing support.

Five test concepts during were considered during the initial phase. After careful evaluation, NAVAIR chose to move forward with TAC Multiplexor. It has Solid State Multiplexers built-in to the modules. The TAC Multiplexers provide programmable connections from the chassis 2A14 and 2A15 motherboard pins to the AWTS measurement bus. TACs connect the AWTS to all of the chassis external connector pins. Modules have small (about 15 pin) connectors on top that provide power, measurement bus access, and multiplexer control (Figure 1).

TAC Multiplexer Basic Setup & Test Concept

- Removal of electronic modules from the chassis before test
- Insertion of modules designed for the test program which provide measurement access to the 2A14 and 2A15 motherboard electrical interconnects
- Connection from AWTS to the chassis external connectors with TACs
- A measurement is a collection of samples collected at a constant sample rate (period). Each sample is a measurement

of the instantaneous resistance which is used to detect open or short. The number and rate of sampling are programmable and determine the time required for each measurement, time to complete all measurements, and the probability of detecting an intermittent during vibration testing. The sample rate should be faster than the vibration frequency so a sample is made near the peak displacement of any moving UUT parts. If for example, vibration frequency is 60Hz then a possible approach would be to take 40 samples at $60 \times 8 = 480\text{Hz}$ which would sample for 5 cycles of vibration and take about 100msec (83msec + overhead).

TAC Multiplexer Concept Description

- Uses a TAC with Solid State Multiplexers to measure UUT motherboard pins.
- All motherboard pins can be measured.
- A TAC connects AWTS to the top of modules that are inserted into the chassis. This provides power, control, and measurement bus to the module Solid State Multiplexers. Any combination of motherboard pins can be connected to the AWTS measurement bus through the Solid State Multiplexer. Control of the multiplexer is through the RS485 interface connected to the AWTS CPU (laptop).
- All external connectors are connected to AWTS with TACs.
- Test program makes one test for shorts and one continuity test for every connector pin that is part of the circuit. If a short is detected, then a measurement scanning routine is executed to identify the reference designator and pin that is shorted to this circuit.
- Use standard AWTS system, TCU plus 1 Switching Module (SM) (1152 points) and CPU

- Test program runs from ELITE (the operating system employed by the AWTS)
- Any type of measurement can be made with the module multiplexers as long as the stimulus used does not exceed the limits of the multiplexers.

TAC Multiplexer Concept Capabilities

- AWTS Self-Test and Alignment are still valid. (TACs are not connected)
- No special calibration/alignment required.
- Multiplexer switch topology is the same as the AWTS switch card relay topology.
- Multiplexers have ESD protection.
- Modules can be verified by connections to a loopback connector and executing a loopback verification test.
- A total of 3419 measurements are required for a complete test. At 100msec per measurement about 342 seconds, or slightly less than 6 minutes, is required to make all measurements. Continuously cycling through the measurements during vibration testing would test each pin 5 times in about 30 minutes.

Testing

Through interpolation of the drawing and technical manual information, the motherboard/module connectors were identified as NAFI types, with aspects of the configuration identified under MIL-DTL-28754 and MIL-C-28859/2D (Figure 2). The motherboard contacts are a tuning fork style and the mating contacts are blades oriented in line along each row (Figure 3). For testing the motherboard, the connectors used for the test interface are required to emulate those used in the modules. The module connectors were identified through the tech manuals, but the component parts included various other elements which were not required for testing. These included the mounting features for the module heat exchangers, grounded pins, and flex-print circuits which added cost and did not provide the required circuit isolation for testing.

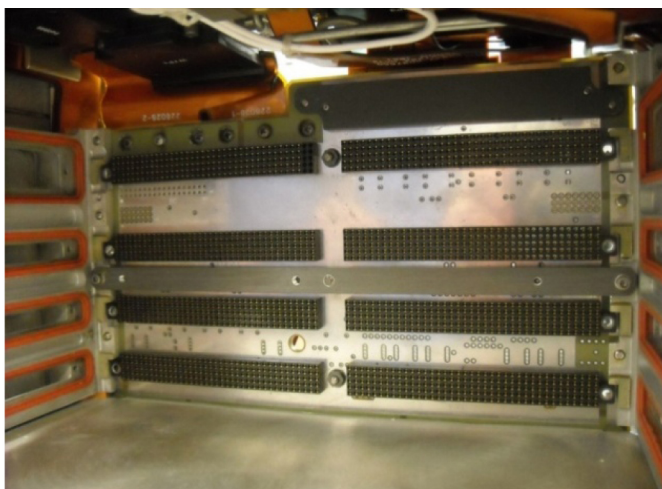


Figure 2. Typical NAFI Connector Interface



Figure 3. Tuning Fork-type Contact (M28859/5A), Serviceable and Damaged Shown

Once the TACs, modules and test software were complete, the team conducted software and TAC interface verification at NAS Miramar, MALS-11 Avionics and NAS North Island FST CASS test facility, June 2011; followed by vibration testing at NAS Patuxent River, in July 2011.

MALS-11, MCAS Miramar provided a part number 3525026-110 (Fleet representative) chassis for validation/verification (val/ver) which was believed to be a known good unit. The use of this TPS to test the chassis enabled us to identify several wiring faults (opens). Once the faults were validated, the chassis was repaired and returned to service. During this val/ver effort, there were several persistent faults identified, which could not be validated with Fleet chassis. A known good asset was required.

In order to validate the source of several open wire discrepancies identified by the TPS, there was a need to show which one was correct; the WRA chassis wiring, the wiring diagrams provided, or the TPS itself. For the final validation, the team was invited to NAS North Island to test the "golden" chassis. Static testing was conducted, and the NAVAIR Wiring Team & FSTs agreed that the TPS performed to expectations, and that it matched the actual wiring chassis configuration. The validation effort proved and identified several wiring diagram errors, which were turned over to the FST for corrective action. At this point the TPS was val/ver'ed and the static test was accepted. Follow-on work focused on the dynamic and environmental testing elements.

A new holding fixture was designed and manufactured to enable the vibration testing. This fixture was designed to withstand repeated use at the maximum qualification test requirements for both max amplitude and frequency vibration. The drawing is on file with the NAVAIR Wiring Team. Vibration (Dynamic) testing was performed in July 2011 and again in September and October 2011 at NAS Patuxent River. The first test focused on seven -110 RR chassis from FRC Mid Atlantic at NAS Oceana, serial numbers TNW853, SGY135, SGY103, 0049, TFG393, TFG358, and TNW513. The TPS collected results and measurement data during test execution while additional information, such as repair actions and visual inspection of the chassis were also recorded (addressed later in this report). The TPS performed to expectations and the vibration test function delivery was accepted. During this test period, it was determined that the initial ten test loops during the vibration