Automated Fault Generation and Characterization for Data-Driven Wire Health Management

Sundeep Jolly, Mission Critical Technologies, Inc.
PI: Kevin Wheeler, Ph.D.
NASA Ames Research Center, Moffett Field, CA, 94035
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Recently, there has been an increased demand for robust, reliable, and minimally invasive techniques for wire health evaluation in aircraft. Despite advances in hardware systems for confirming fault existence, there still exists a lack of robust software-based approaches for accurately diagnosing and precisely locating faults. A novel model-based diagnostic system for wire health management has recently been proposed [1] and employs a data-driven paradigm for effectively characterizing, simulating, and modeling several types of common faults occurring in aircraft wiring. Simulating and modeling various fault types for this system requires a sufficient quantity of reliable data concerning the electrical character of the fault at hand. Presented here are two approaches for creating and characterizing faults due to chafing on wiring.

Recent FAA studies have concluded that 55% of wiring faults commonly found in aircraft are due to a breach or chafe in the wire's insulation [1]. Chafing can develop in aircraft wiring due to random vibrations in harnesses and also due to wire-on-wire abrasion in cabling bundles. The approaches presented here attempt to recreate chafing faults due to random vibrations and wire-on-wire abrasion.

To recreate chafing faults due to random vibrations, a setup (hereafter referred to as the shaking ablator) consisting of a shaking pivot, conductive abrasive rod, and cable mount is employed. An insulated, shielded twisted-pair (STP) or coaxial cable (i.e., the cable-under-test) is mounted between the abrasive rod and shaking pivot. Such a setup causes the cable-under-test to abrade (due to the abrasive rod) with each vibration of the pivot. The shaking pivot is driven at a rate of 10 Hz (corresponding to 10 chafe cycles per second on the cable-under-test).

To recreate chafing faults due to wire-on-wire abrasion, a setup (hereafter referred to as the wire-on-wire ablator) consisting of a motor-driven translation shaft, conductive and abrasive wire, and wire mount is employed. An insulated, shielded twisted pair cable is mounted such that there is substantial contact area between its insulation and the abrasive wire. The abrasive wire is mounted on a motor-driven translation shaft and thereby is driven to oscillate in one-dimension such that the cable-under-test is chafed. The shaft is driven by the PID-controlled motor and set to oscillate at a rate of 10 Hz (corresponding to 10 chafe cycles per second on the cable-under-test).

For both cases, retrieving the electrical character of the faults created is accomplished using time-domain reflectometry (TDR) and time-domain transmissometry (TDT) techniques through the cable-under-test. In TDR and TDT, a very short (i.e., < 100 ps temporal width) voltage pulse is sent through one end of the device-under-test. Treating the device-under-test as a transmission line, the complex input voltage $V_i(t)$ is partially reflected and partially transmitted (i.e., $V_i(t) = V_r(t) + V_t(t)$). The nature of the reflected and transmitted waveforms depends highly on the characteristics of the device-under-test (e.g., characteristic impedance, termination, faults). Careful analysis of the reflected and transmitted waveforms can retrieve information regarding the existence, type, and location of faults on test STP or coaxial cables.

Two approaches are used in the laboratory to perform the TDR and TDT measurements. The first uses the Agilent 86100A wide-bandwidth oscilloscope for data acquisition with the Agilent 54745 TDR dual-channel plug-in module for pulse generation, TDR measurements, and TDT measurements. In this case, the input end of the DUT is interfaced to Channel 1 of the TDR module and the output end is interfaced to Channel 2. The second utilizes a Tektronix AWG7051 arbitrary waveform generator (AWG) as the step generator and a Tektronix DPO71604 digital phosphor oscilloscope for data acquisition. In this case, the load end of the DUT is coupled (via a high-frequency directional coupler) to both the AWG and to the oscilloscope and the output end is interfaced to another channel on the oscilloscope. In all cases (including those where coaxial cable is used), one conductor is left floating while the other conductor is tied to the shielding of the cable. At the point of chafing to the shielding, there is a perceptible difference in the characteristic impedance of the wire-under-test (i.e., the electrical character of the shielding). The connectivity arrangement utilized here allows for retrieval of the electrical transient response of the shielding as a function of chafe size, depth, position, and number.

In all cases considered, the most notable parameter of interest is the number of chafe cycles needed to break through the insulation of the wire-under-test and expose the shielding of the cable. As chafing progresses with progressive cycles of the shaking ablator or wire-on-wire ablator, a continuity test between the abrasive rod or abrasive wire and the shielding of the wire-under-test is used to determine whether the insulation of the cable has been breached. In order to determine how progressive chafing (after the initial breach of the insulation) affects the electrical character of the wire-under-test, the TDR and TDT measurements are taken at set chafe cycle intervals as the chafe continues to grow.

For all cases, all instrumentation is controlled by a centralized computer employing several automation schemes developed in LabVIEW. The LabVIEW scripts provide a robust automation scheme for controlling the shaking ablator and wire-on-wire ablator, performing the TDR and TDT measurements with both approaches described previously (i.e., with AWG/oscilloscope or TDR module), collecting and saving measurement data and process information (e.g., number of cycles before insulation breach occurs, consistency of the ablators in chafe cycle frequency). Development of such automated measurement schemes is crucial for consistent experimentation as well as ease of repeatability.

The responses of the chafed wires to TDR stimuli collected during this data acquisition will be used in modeling faults and creating a readily accessible fault library. Precise models for wire faults will allow for commercial applications.

[1] K. Wheeler, X. Twombly, J. Friederich, and D. Timucin. "Model-based Diagnostics for Wire Health Management." Aging Aircraft 2008, Phoenix, AZ (2008): 942.