Transfer Impedance Measurement of Flexible Printed Wiring Board Cable Shields for Use in Crewed Space Flight

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Over the years, materials and processes for manufacturing flexible printed wiring board (PWB) cable assemblies have improved to such a state as to make them attractive candidates for use in crewed space flight. The reliability, low mass, and producibility of flexible PWB cables in lengths up to 2 m (7 ft) make the design an ideal candidate choice. However, there are additional requirements for the wiring of crewed spacecraft, and among these is the transfer impedance of the shields of interconnecting cables and harnesses. NASA's International Low Impact Docking System (iLIDS) project team has taken the lead in attempting to qualify flexible PWB cable designs for critical space flight systems in an effort to reduce overall mass. As part of the qualification process, an effort was undertaken to measure the transfer impedance of representative cables. The team tested two different flexible PWB cable designs. Both cables were identical in construction except for the shield designs, which differed only by the addition of stitching vias along the edges of one of the cables. The team used a triaxial apparatus to measure each of the two cables. The length of RG-58 coaxial cable was also measured using the same triaxial apparatus, so as to obtain data for comparison with published results from independent testing of the same cable type. By so doing, the accuracy of the test apparatus setup and measurement technique would be established.

Cable and Fixture Design, and Test Setup

Flexible Printed Wiring Board Cable Construction and Shield Design

The flexible PWB cables were constructed using a rigid-flex laminate process. A rectangular area at either end of the cable, fabricated using a rigid PWB process, provided structural support for mounting connectors terminating the cable shields to special fixture plates and backshells. The remaining length of the cable was fabricated using a flexible PWB process, allowing the cable to be formed into place on installation. Pioneer Circuits (Santa Ana, California) provided technical assistance and design of the layer stack-up for the rigid-flex construction.

Inner-layer conductors and outer-layer shielding were formed by copper foil laminates having thicknesses of 0.0014 in., with a 0.001-in.-thick Kapton® interlayer between conductors. The shield layers formed the outer most copper layers in the stack-up. Further shielding of inner layer conductors was provided by perimeter guard traces, 0.030 in. in width and placed along the cable edges. Both cable shield designs incorporated these features. Vias, 0.02 in. in diameter with 0.04-in. center spacing, were placed along the entire length of both edges of one of the cables to be measured. The vias were positioned to provide an electrical connection between the top, bottom, and guard trace shields, thus providing shielding with much smaller apertures to electromagnetic fields.

The shielded conductors were brought out through press-fit socket contacts installed in the rigid PWB portion of the cable. This allowed for connection to specially designed plates with which to drive and measure signals in the conductors of the flexible PWB cable. The flexible PWB cables used in the measurements were approximately 31 in. long and 0.8 in. wide, the length being decided prior to the design and fabrication of the transfer impedance fixture hardware.

Test Fixture

A cylindrical test fixture, based on the triaxial measuring setup of International Electrotechnical Commission (IEC) standard 62153-4-4, was fabricated from a 3-in. inner diameter schedule 40 copper pipe, wall thickness approximately 0.24 in., made of Electrolytic Tough Pitch (ETP) 110 copper. End plates and intermediate mounting plates of varying thicknesses were fabricated from flat stock ETP 110 copper and nylon material. Figure 1, taken from IEC 62153-4-4, illustrates the electrical schematic of the triaxial fixture.

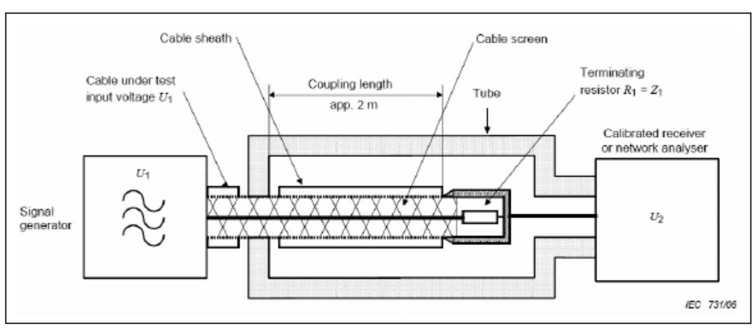

Fig. 1. *Electrical schematic diagram.*

Test Setup

Primary measurement equipment consisted of a vector network analyzer (VNA) with a scattering parameters test set, and an impedance adapter for the cables under test. A secondary setup using a signal generator, a spectrum analyzer, and an automated software controller, was used for comparison measurements, and to provide confidence that the data collected and displayed by the network analyzer were accurately processed.

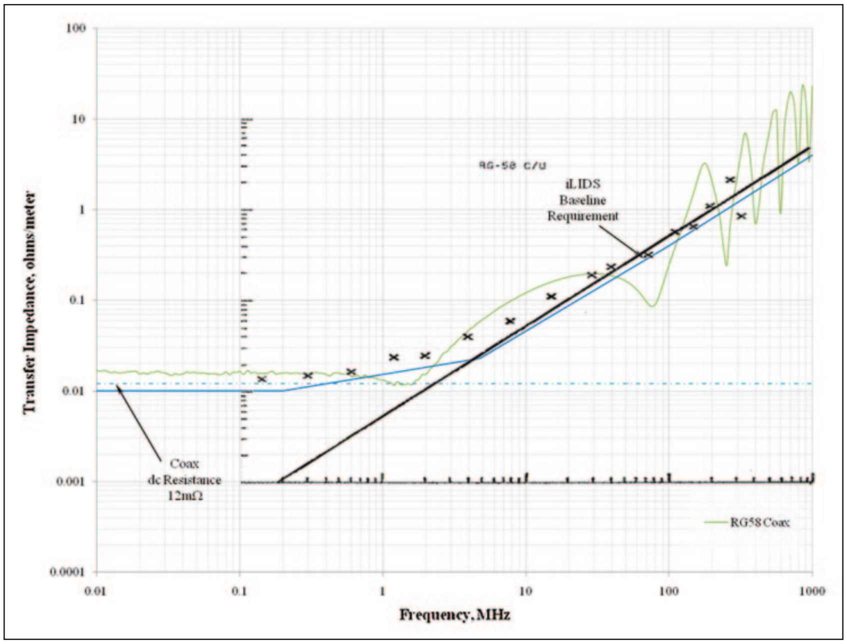

Fig. 2. *RG-58 data compared to independent data.*

Setup calibration, impedance matching, and measurement procedures using the VNA were in accordance with IEC 62153-4-4. Setup calibration, impedance matching, and measurement procedures using the spectrum analyzer (SA) and signal generator (SG) were in accordance with standard laboratory practice.

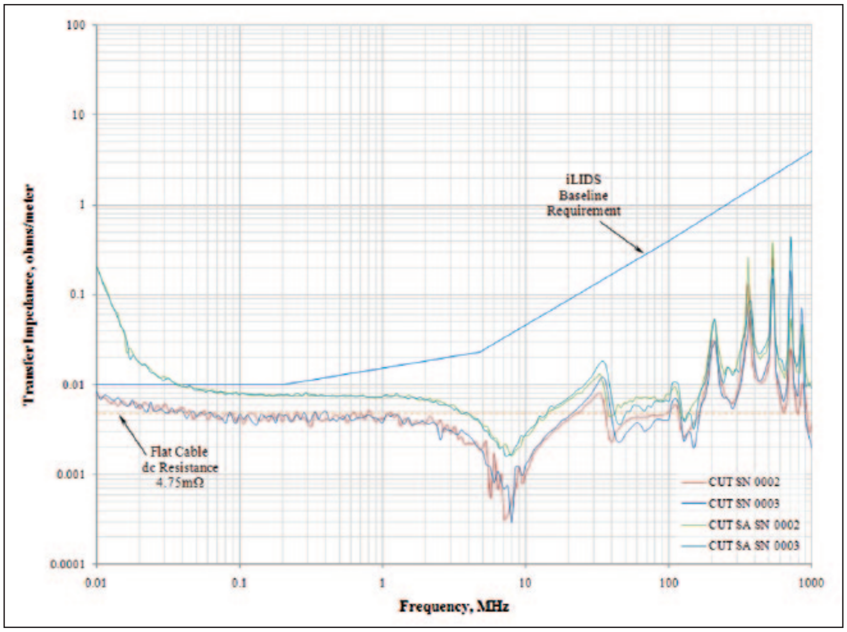

Fig. 3. *Comparison of vector network analyzer data to spectrum analyzer/signal generator data.*

Data Collection and Review

Data collection was straightforward for both setups. In the case of the VNA, no further effort was required other than to set up the instrument using a standard, short, open, and loaded dual-port calibration. The setup using the SA and the SG was a bit more complex, requiring some minor programming to the computer controller to run the SG and collect the data from the SA. The data from the VNA were presented and taken from the instrument. The data from the SA/SG setup were taken from the computer controller after some minor interface processing. The data were available in both cases as a XXX.CSV file, as well as a XXX.BMP file.

As a means of calibrating the system to a known result, a length of RG-58 cable was introduced into the fixture and measured from 10 kilohertz to 1 gigahertz. The data were then plotted and, as shown in figure 2, independently collected data for RG-58 transfer impedance was laid over the resulting curve for direct comparison. The black straight line and the x's are from the independent data source. Examination of this comparison yields good comparison, and establishes confidence in the ensuing results for the flexible PWB cable measurements. The iLIDS baseline curve is the solid blue line, and the measured data are represented by the green line.

With the fixture thus calibrated, data were then collected for the flexible PWB cables using both measurements setups. Figure 3 plots the data from both sets of measurements for review. Examination of these data show good agreement between the two techniques in terms of frequency behavior, but the magnitude of the data collected using the SA/SG setup appears to be slightly high. The data in the lower frequency range should be close to the direct-current resistance of the cable. The data collected using the VNA do show excellent agreement with the direct-current resistance value. For this reason, the VNA data are considered to be the most accurate representation of the flexible PWB cable transfer impedance. Again, note the solid blue iLIDS baseline requirement.

Finally, the VNA data are plotted in figure 4 against the RG-58 data and the iLIDS baseline for direct performance comparison.

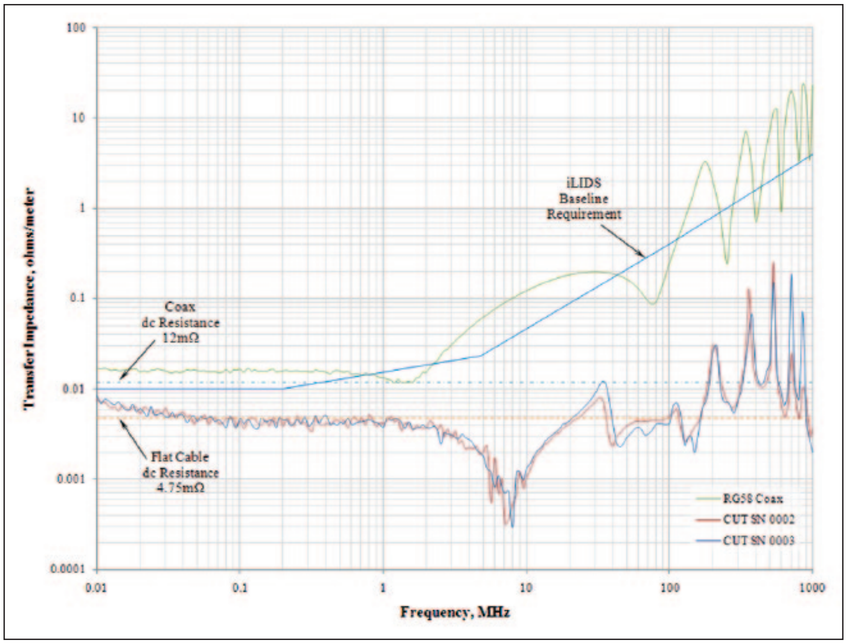

Fig. 4. *Comparison of RG-58 data to flexible printed wiring board cables.*

Conclusion

The transfer impedance of the integral shields of two flexible PWB cable designs was measured and shown to be superior to the baseline requirement, thus paving the way for future integration of this type of cable in the iLIDS project, and potentially in other space vehicle projects as well.