SECTION V. RELIABILITY

5.1 Introduction

The FCC interconnecting systems have not seen extensive enough use to provide statistical data on failure rates, criticality, and reliability figures for direct comparison to RWC interconnecting systems. Therefore, the reliability comparison will be made primarily from an analysis of the materials, the cable and connector constructions, the cable heat dissipation, the plug assembly methods, the harness installation, and the system technical performance. Analytical studies on quality and dependability of electrical interconnecting systems using RWC show generally current leakage, conductor breakage, and junction failure as major points of concern. All these will be analyzed in the following paragraphs.

5.2 Cable

RWC harnesses are made up of individual conductors with insulation materials extruded, or wrapped in layers, over the conductors. To facilitate wire stripping, the insulation normally has a low-shear bond strength to the conductor. This, together with the relative low-tensile strength of the RWC insulation (5, 000 to 10, 000 psi), limits the structural tensile strength of the individual cable to that of the conductor. The random nature of the conductor routing, and bundle tying in the RWC harness, does not provide load sharing of the individual cables. Therefore, the axial and bending stresses permitted on RWC harnesses are much less than the average for combined conductors. In many applications, such as bending or twisting, the allowable load could approach the stress allowable of the conductor in an individual cable.

In comparison, FCC insulation materials are laminated or bonded to the conductors to provide a homogeneous structure having high collective strength.

Polyester (Mylar) and polyimide (Kapton) insulations, commonly used in FCC constructions and those specified by MIL-C-55543 have tensile strengths of 25, 000 and 20, 000 psi, respectively. This strength, which is approximately five times that of common insulations used with RWC, is added directly to that of the conductors to provide a cable strength of many times that of an equivalent RWC harness. In addition, any stress or strain placed at a termination area having proper strain relief will be shared by all conductors.

As the conductor size requirements become smaller and smaller for future programs utilizing integrated circuit electronics, the reliability advantages of the FCC become greater and greater. This is the direct result of the mechanical load-sharing characteristics of the FCC system and the automated, multiple-termination systems used.

Numerous mechanical, environmental, and electrical tests have been performed on various FCC configurations to verify the properties which contribute to the increased reliability as described above. NASA/MSFC has conducted and contracted numerous tests on various cable configurations. The U. S. Army Electronics Command at Fort Monmouth, New Jersey, has conducted an extensive study to verify the mechanical and electrical characteristics of FCC.

The inspection of nonshielded FCC is greatly facilitated by the translucent insulation used. This permits visual inspection of all conductors and insulation layers. Many cable faults covered by the opaque insulation of most RWC systems would be readily apparent in the FCC system.

5.3 Connectors

The reliability of electrical connectors is a function of the connector design, the materials, the termination system used, and the method of connector assembly. Much experience has been gained over the years in the design and fabrication of RWC connectors in termination techniques and in connector assembly. As a result, a high degree of confidence and reliability has been established. All RWC connector experience has been applied to existing and will be applied to future FCC connector systems. In addition, the FCC connector offers certain inherent advantages over that of the RWC system.

In the NASA/MSFC conductor-contact connector system, at least one electrical joint per conductor is eliminated by using the FCC conductor as the plug contact. Furthermore, the carefully designed contact spring of the receptacle, having a spherical contact of controlled radius, spring rate, spring deflection, and contact force is a built-in warranty for reliable, continuous performance.

On all FCC connector systems designed for high reliability and production, terminations are made to the connector contacts on a "by-layer" basis; therefore, the conductors do not require individual stripping, handling, or forming. With proper design and tooling, there is no probability of individual stressing of conductors, insulations, or connector contacts.

5.4 Harness Assemblies

An increase in reliability of FCC harness assemblies is the result of several factors. First, the termination of the FCC to the FCC plug is made in an automatic or semiautomatic operation. Instead of handling hundreds of individual conductors for identification, jig-board routing, preparation for termination, termination, and assembly into connectors, as is required on the RWC system, the FCC system requires only the handling of several cables to build an equivalent harness.

FCC assemblies can be designed for much simpler interconnecting harnesses. The simpler harnesses are easier to build and inspect; thus, a reliability improvement is gained.

Very small conductors, of 26-gage equivalent or less, can easily and reliably be assembled and terminated in FCC harnesses. Extreme caution must be exercised with a major reliability degradation potential when these smaller gage conductors are used on the RWC system.

The FCC harnesses also have greatly improved abrasion resistance over RWC harnesses. This increase in reliability is the result of the improved mechanical properties of the insulation materials plus the geometric configuration of the FCC. The RWC insulation varies from 5 to 15 mils in thickness. When an RWC bundle makes physical contact with an interference or abrasion surface, only the insulation on the outside cable need be penetrated to effect an electrical short circuit. This radial surface offers relatively little abrasion resistance. With larger bundles, the forces will generally be greater and the probability of failure is even higher.

The improved insulation on the FCC is generally much thinner (about 3 mils thick). However, instead of a small-radiused area of one conductor coming in contact with the abrasion medium, a contact line, the width, of the FCC is established. As a result, the FCC harness will withstand many times the abrasion that can be tolerated by the RWC harness. The FCC insulation edge margin is approximately 0.10 inch to provide increased abrasion resistance on the cable edges where concentrated loads could be applied.

5.5 Harness Installations

A review of Figures 1-1 and 1-2 gives a clear indication of the improvement and simplification in harness installation that can be achieved with the FCC interconnecting system. The much-simpler FCC harnesses make installation and replacement more reliable. Each FCC harness can be easily routed into and supported with the major harness runs. The number and complexity of supports and attachment clamps are greatly reduced. In addition, the series of clamps developed have captivated hardware so no loose parts can be dropped or misplaced during installations. All sharp edges and protrusions were also eliminated.

The cleaner routing and support, with the major space reduction for FCC, contributes heavily to increased reliability. Installations can be made with fewer protrusions that could be used as handholds or would be subject to maintenance damage. The major space savings achievable with FCC will have the effect of making less dense installations with more room for installation and serviceability.

The FCC weight saving will result in less massive installations with a reduction of stresses in the various support areas.

FCC can be bonded directly to basic structure in many instances to provide the ultimate in installation simplification, harness protection, light-weight support, and resultant reliability. Bonding to structure is especially applicable to the longer harness runs between major distribution areas, in tunnel runs, and in airborne external installations such as those routing to transducers.

5.6 Heat Dissipation

A major reliability aspect is the verification of performance of the system being used. During the past few years there have been many claims made and curves and charts published on the current-carrying capability of FCC and its comparison with RWC. The recently completed study and testing by NASA/MSFC has resulted in an unquestionable comparison between the load carrying and thermal characteristics of FCC and RWC. Extensive comparison tests were made in air and vacuum with various directly comparable bundles. The test results indicate that the temperature rise of FCC in air is approximately: 50 percent less than RWC for a 25-conductor, one-layer FCC cable; 40 percent less than RWC for a 75-conductor, three-layer FCC cable; and 10 percent less than RWC for a 250-conductor, 10-layer FCC cable.

The temperature rise of FCC in vacuum is approximately: 60 percent less than RWC for a 25-conductor, one-layer FCC cable; 50 percent less than RWC for a 75-conductor, three-layer FCC cable; and 35 percent less than RWC for a 250-conductor, 10-layer FCC cable. All the tests were made with bundles isolated, except in their support areas. When FCC is bonded to structure, which then acts as a heat sink, even greater heat dissipation with reusltant lower temperature will be experienced.

Section III contains instructions, curves, and correction factors to predict temperature rise versus current for FCC conductor cross sections listed in MIL-C-55543. The predictability of the resultant temperature rise and the appreciable lower operating temperature of the FCC are major contributions to reliability.

5.7 System Performance

The use of FCC permits the prediciton of the specific electrical characteristics and assures the repeatability from unit to unit of the interconnecting harnesses with the resultant reliability improvement in system performance.

RWC systems, with random routing of individual conductors in the cable bundles, have no control over the placement and resultant electrical characteristics between conductors. To overcome this shortcoming, excessive shielding and numerous bundle runs have been utilized over the years to achieve the required system performance. This has resulted in an overdesign for worse-case conditions. Excessive weight and space were required for the RWC systems with the reduction of reliability previously described. Even with all these precautions, EMC tests on the required percentage of end items indicated that subsequent units, supposedly interwired identically to previous units that have successfully passed the tests, needed additional circuit isolation.

With the FCC system, each conductor location is controlled in relation to all other conductors and to the ground plane throughout the entire interconnecting harness system. This permits the proper selection of the simplest system with the most desirable electrical characteristics and assures that all units will perform identically. It further encourages, and even forces, the system designer to consider the interconnecting harness system as components of the overall electronic systems. When he thoroughly understands and applies this component concept and utilizes the available configurations of FCC, a major step in simplicity and reliability will be achieved.

The capability of FCC harnesses to act as a built-in line-filter to effectively reduce spurious electrical noise and disturbing signals is discussed in Section III. This provides an increase in reliability by eliminating a separate filter unit with its individual components and interconnections that are possible sources of failure.

5.8 Conclusions

In conclusion it can be stated that the use of the FCC system offers many potential reliability improvements over the RWC system. These include: greater collective strength and greater abrasion resistance for FCC; fewer junctions, simpler assembly and less probability of overstressing individual contacts and conductors in FCC connectors; simpler, smaller, and lighter-weight harness assemblies and installations; improved heat dissipation provides cooler operating temperatures for the same electrical loads and equivalent conductor cross sections; and improved and predictable system performance, repeatable unit after unit.