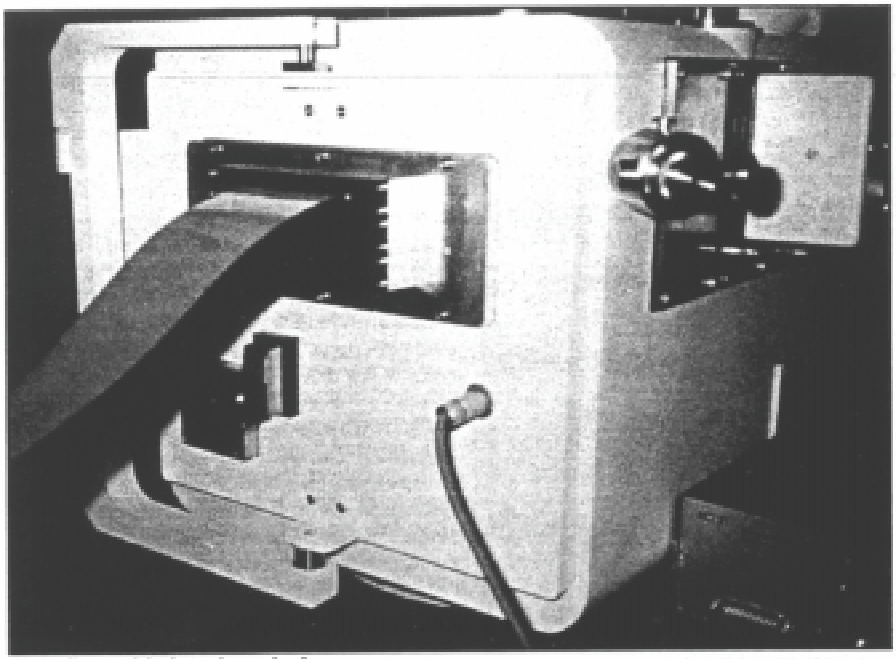


New flex cable interface design.

PAVE-FLEX BY PAVE TECH.

High Frequency/ High Density/ High Vacuum Transmission Line Interface

PAVE–Flex® solves high frequency high vacuum PAVE seal design.

By Straty Argyrakis, IBM East Fishkill, East Fishkill, NY

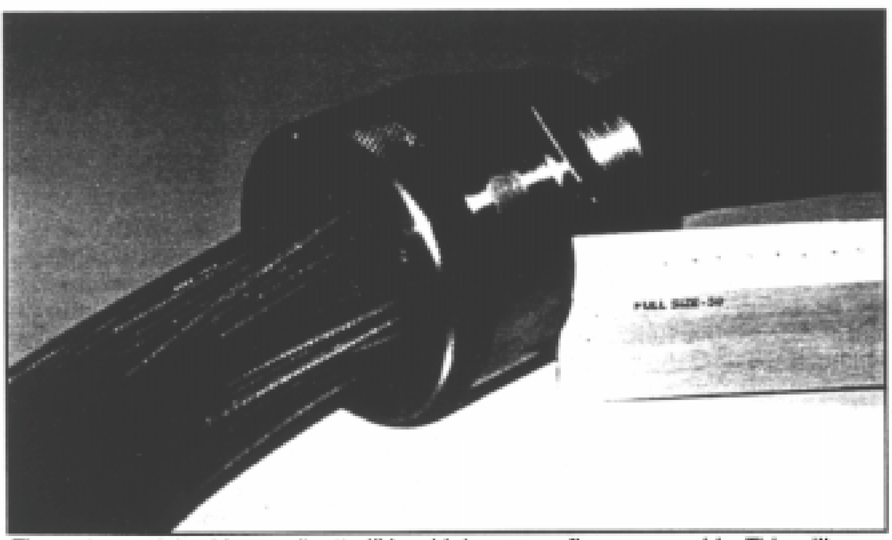


Figure 1, coaxial cables are "potted" in a high vacuum flange assembly. This will facilitate a hermetic entry point into the vacuum chamber.

All integrated circuits (ICs) employed in the electronics world today must be electrically tested to insure proper performance and reliability. Many of the test items reside in very-high-vacuum environments where pressures of 1 x 10^{-7} Torr are common. With the advent of 500 MHz, 512 pin test systems and the active pin count of new devices approaching 299 signal pins in a 25 x 25 pin-grid-array (PGA) format, challenging interconnection problems present themselves to the engineer responsible for the testing and interconnection of these systems.

High Vacuum Environment

The ultra-high vacuum specification of 1 x 10^{-7} Torr imposed by the E-beam voltage contrast system is the most demanding of all the requirements. Traditionally, in an application where only a limited number of interconnection cables are needed (60 signals typical), Rg-316/U (or similar) coaxial cables are "potted" in a high vacuum flange assembly in order to facilitate a hermetic entry point into the vacuum chamber (figure 1). This traditional approach suffers both physical and electrical limitations.

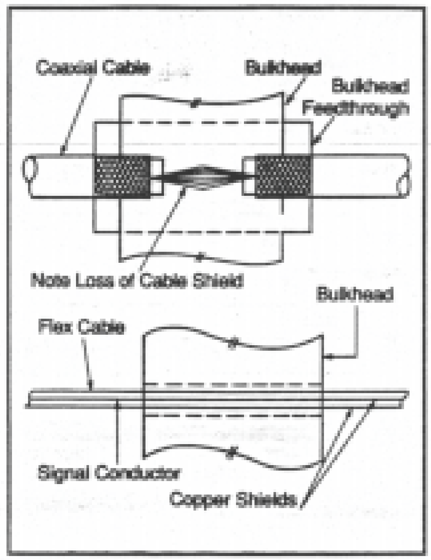
By the nature of the construction of typical coaxial cable, voids exist in the dielectric and center conductor medium of the cable. As a result of these voids, air molecules are trapped and reside in these areas when the cable is exposed to the atmosphere when the vacuum chamber is vented and a device is installed or removed from the system for analysis. The air molecules pumped out of the cables by the system's vacuum pump appear as a virtual air leak called outgassing. This outgassing phenomena causes large increases in pumpdown time, which severely impacts operation productivity.

The traditional coaxial cable employed in a high-vacuum bulkhead penetration requires structural modifications resulting in a discontinuity in the transmission line. It is necessary to break down the coaxial potting compound cable to its smallest component before backfilling the cable with high-vacuum potting compound to create the seal (figure 2). By disturbing the dielectric and breaking characteristics of the cable, a mismatch in the transmission characteristics is undesirably created. The mismatch creates reflections in the incident signal and results in distortion loss of valid data (figure 3).

Pave Technology Co. comments

1. Coaxial cable PAVE seal have comparable vacuum seal integrity though a longer pumpdown period may be required to degass the cable.
2. Low frequency applications would allow the use of coaxial cable PAVE seal
3. PAVE Technology can usually seal existing flex circuits or can custom manufacture flex circuits.

Figure 2, traditional coaxial cable has to be "broken down" to its smallest component before backfilling with a high-vacuum potting compound. Flexible cable does not have to be "broken-down" to be potted, thus eliminating the mismatch in the transmission characteristics associated with coaxial cable.



High Vacuum Interconnect

A high frequency, high density, stripline/microstrip environment flexible cable test fixture was designed and developed to address these interconnection problems. This new design provides a "Kapton" 50Ω impedance interconnect system which spans a 48" length and has a signal density of 60 signal conductors in a 0.0558" cross-sectional area. This small area, in conjunction with the laminate construction, makes the flexible cable a candidate for high-vacuum applications.

The main body of the flexible cable is constructed in the stripline domain (figure 4) and requires that a copper ground plane reside above and below the signal plane (separated by the dielectric) providing complete isolation from the external environment. This design results in a pure transmission line through the vacuum chamber bulkhead; the impedance integrity is maintained throughout the length of the cable insuring a high quality interconnection.

The Solution to Vacuum Outgassing

The flexible cable's laminate construction and the Kapton dielectric material employed solve the problem of outgassing in the high-vacuum environment. The flexible cable is constructed of inert materials laminated in such a fashion that there are no voids to trap air molecules (figure 5). This design eliminates the traditional pumping load to the vacuum system presented by the coaxial cable resulting in an overall improvement in through-put and device test reliability.

Most device failure analysis tools require moving/positioning the device under test (DUT) on an X, Y, Z stage with resolutions of up to 100 µm typically under motor control. It is often necessary to have the electrical interface (256 coaxial connections) connected directly to the stage assembly. The coaxial cable harness can result in substantial tension load to the stage assembly, often impairing the free travel of the system resulting in binding, backlash, premature failure and test failure.

Solution to Signal Density

The current flexible cable design exhibits approximately four times the signal density of traditional coaxial cable. The flexible cable signal conductors are 0.004" wide and spaced on 0.050" centers with 20 mil ground plane spacing, resulting in a signal density of 500 conductors per square inch versus 125 for RG-316U coaxial cable.

Future Test Requirements

Apart from the mechanics and physical problems discussed, future testing will require ever increasing connection counts. Existing electronic devices, including microprocessors and ASICs, have active pin counts approaching 299 pins in a PGA format. Future requirements can only increase with time.

Test Fixture Specifications

The test fixturing specifications are a combination of achievable manufacturable design specifications and future test requirements.The specifications imposed by the tester itself are uncompromising in nature and some adjustments must be implemented to compensate for the imperfect world of transmission lines. The test fixturing was designed for a minimum three-year life expectancy.

The specification for bandwidth requires DC to 300 MHz into 50Ω. Most test system manufacturers have standardized to 50Ω pin electronics drivers and can compensate for up to 10 ns of delay in the tester. A DC resistance specification of 5Ω maximum was selected as a manufacturing limitation and is acceptable in the digital test world where series damped termination[1] is the technique employed to terminate the DUT.

Flexible Cable Design and Construction

The dielectric material chosen for the flexible cable was Kapton. Many different materials were considered and reviewed, but Kapton was selected for its flexibility and manufacturability. The cable was manufactured by an outside vendor.[2]

Stripline domain was selected for the body of the flexible cable for its shieldability (with some sacrifice in flexibility) where external crosstalk could impair data integrity. Stripline technique mimics the transmission line characteristics of coaxial cable in that it is a signal conductor surrounded by a groundplane separated by a homogeneous dielectric. A microstrip region was employed for the connector interface. The microstrip dimensions were modeled as part of the zero insertion force connector used in the fixture. The exact specifications for the stripline and microstrip dimensions were modeled on

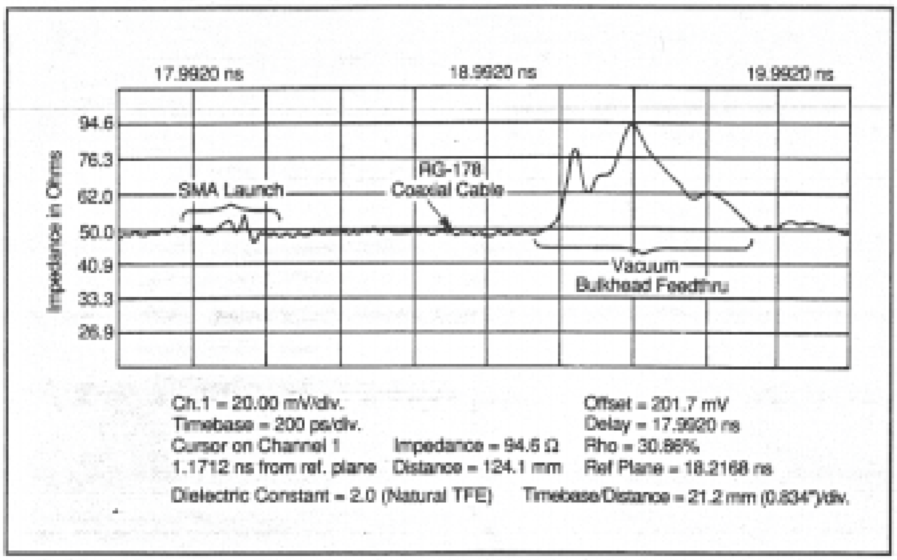


Figure 3, TDR measurement of the impedance mismatch associated with the coaxial cable in the high-vacuum bulkhead penetration .

a 386 based system. The formulas programmed were from a variety of publications listed and finally a specification for the prototype was derived. The first-run prototype was a 30 conductor, 0.100" spaced, 0.005" conductor width cable manufactured in a 48" length.

Connector Selection

Two connection schemes were selected to terminate the flexible cable, a 50Ω impedance connector tester interface,* and the other a zero insertion force (ZIF) flexible cable connector to the DUT.

The 50Ω connector selection was based on the common 0.100" center to center, 0.025" square pin, scheme used by a majority of test system manufacturers for DUT pin interconnection. The connector offers a controlled impedance environment, which is imperative to the fixture.

The ZIF selection was based on a much more complex series of requirements. First, a connector which could offer a simple means of low wear interconnect without soldering was foremost. The Kapton flexible cable could not withstand the temperatures soldering would impose. Second, the connector must be impedance controlled in order to maintain the signal integrity. This ZIF connector is, by itself, not an impedance controlled connector in any respect, but by engineering the microstrip ends of the flexible cable and the connector as one entity, a near 50Ω transmission line environment can be achieved. In the classic formula for predicting microstrip impedance, one element of the connector wire contact adds itself to the dimension "T", and another element presents itself as a classic wire over a ground plane. The result is a low cost, high quality connector which meets all of the design requirements.

Test Fixture Design

The test fixture uses a motherboard (figure 6) to enable the connection from the flexible cable to the outside world. The motherboard is a microstrip design targeted for 50 ±5Ω (near the limits of manufacturing control for moderate cost), and provides the necessary electrical interface to the ZIF and 50Ω connectors. The printed circuit traces comprising the connector interconnect on the motherboard were designed to be ±0.050" in length to keep propogation delay constant across the fixture.

Ground Plane Integrity

When designing high frequency circuits, special attention must be paid to the ground plane design. Problems can result if discontinuous grounds, inadequate ground via interconnects an insufficient ground conductivity (too thin a copper foil) are used. The problems can range from ground bump and impedance deviation to EMI/RFI radiation. The flexible cable uses numerous ground via interconnects to maintain a high quality electrical connection between the stripline 1.5 oz. copper ground planes. The ground planes are also connected by four copper eyelet feedthroughs. In addition to the ground connection, the mounting screws provide strain relief for the cable.

Vacuum Integrity

The flexible cable components were sent to a vendor[3] for the actual high-vacuum potting of the flange assemblies (figure 7). The vendor employed a potting epoxy*** that featured high vacuum characteristics including a low vapor pressure specification. The flanges designed for this application were constructed of stainless steel 505 and permit a 1/8 x 1.0" potting area surrounding the cable.

The flexible cable fixturing was helium leak checked with a leak check system.† The fixture, including all "o" rings, flanges and potting assemblies was evacuated to a pressure of 3 X 10^{-6} Torr and was checked to the limit of the MS-20: 1 X 10^{-10} Std. CC/s. Future analysis will include residule gas analyzer (RGA) measurements to determine the vapor pressure of the fixture materials.

Electrical Analysis

Impedance and crosstalk analysis was conducted with a time domain reflectometer.†† The results are as follows:

Risetime/Bandwidth
1.50 ns/233.3 MHz
Impedance at 1.5 ns
50 + 10.0/-0.0Ω
Crosstalk (Near/Far) at 1.5 ns
10% (-2 dB) Maximum
Propagation Delay
7.56 ns
DC Resistance
4.0Ω
Dielectric Constant
Er = 3.30 from Measurement

Conclusion

The prototype cable met all the initial design projections save risetime degradation. The vacuum evaluation exceeded expectations in performance. As with

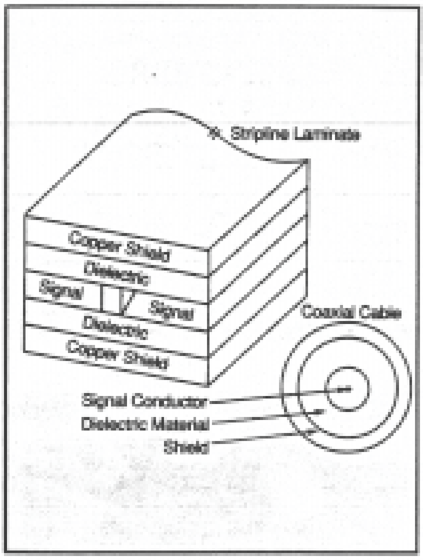


Figure 4, comparison of the construction of coaxial cable and flexible reveals that flexible cable is constructed in the stripline domain.

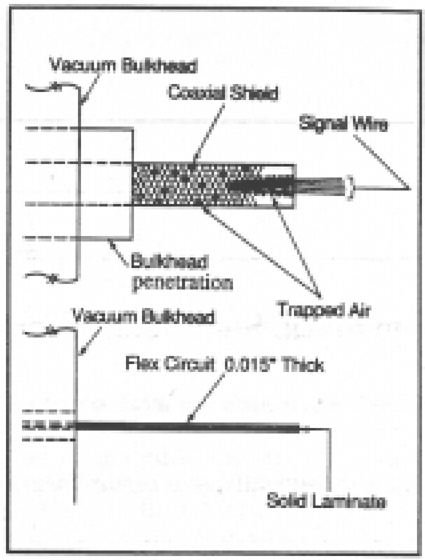


Figure 5, comparison of coaxial cable and flexible cable demonstrates that no air is trapped in the flexible cable while air voids exist in the dielectric of the coaxial cable.

any transmission system, there are compromises to be made to achieve overall system performance. The length of any transmission cable in this circumstance dictates bandwidth: the shorter the length, the greater the bandwidth. It is the responsibility of the designer to prioritize the primary system specifications, i.e., bandwidth, crosstalk, flexibility, length, density, etc., and create the right combination for the application. The flexible cable design solves a multitude of difficult application problems with minimal compromise in performance and shows great promise in future test fixturing designs. Other applications could also include mainframe computer backplane interconnect, high speed hard-disk magnetic head interface applications and underwater high density/frequency applications.

Acknowledgements

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References

1. *MECL System Design Handbook, pp 52-58.*
2. *Interflex Corp., 1050 Perimiter Road, P.O. Box 6188, Manchester, NH 03108.*
3. *Pave Technology Co., Inc., 2751 Thunderhawk Court, Dayton, OH 45414-3445.*
4. *W. R. Blood, MECL System Design Handbook, Motorola Semiconductor Products Div. Inc., Fourth Edition, 1983.*
5. *Mantech for Advanced Data/Signal Processing (VHSIC), Martin Marietta Orlando Aerospace, ADSPMM-88-308-BP, 1988, Prepared for: Materials Laboratory, Air Force Wright Aeronautical Laboratories, Air Force Systems Command, Wright-Patterson AFB, OH.*
6. *Harlan Howe, Jr., Stripline Circuit Design, Artech House Inc., Fourth Printing 1982, LCC 73-81242, SBN 0-89006-010-7.*
7. *J. DeFalco, "Reflections and Crosstalk in Logic Circuit Interconnections," IEEE Spectrum, July 1970.*
8. *S. B. Cohn, "Characteristic Impedance of the Shielded Strip Transmission Line," Transactions IRE, Vol. MTT-2, July 1954.*

**SCI 100 Series manufactured by 3M Corp., St. Paul, MN*

***5597 Series manufactured by Molex, Lisle, IL*

****One version is Pave Seal 150, manufactured by Pave Technology Co., Inc., Dayton, OH.*

†MS-20 Leak Check System by Veeco Services performed by Micro-Electronic Device Specialists, 3 Westview Terr. Poughkeepsie, N.Y. 12603; tel. 914 462.6253.

††54120A/54121T Time Domain Reflectometer manufactured by Hewlett Packard.

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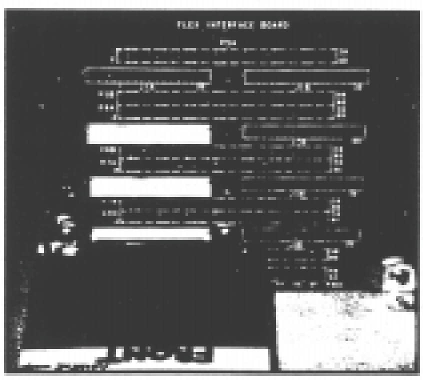

Figure 6, motherboard connects flexible cable to the outside world.

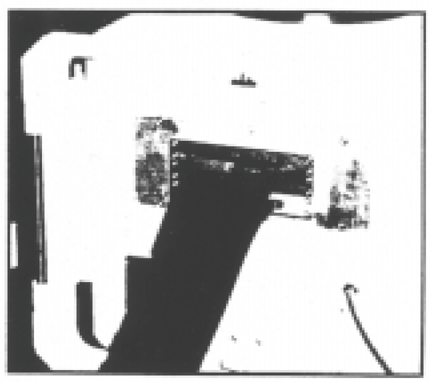

Figure 7, flexible cable was sent to a vendor for the high-vacuum "potting". This flexible cable has been potted and assembled into the test system.