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Electroformed Cables Deliver Performance in Highly Demanding Applications

By Bob Thiele
Semflex, Inc.

As featured on our cover, this microwave cable assembly manufacturing technique is a solution for applications with stringent requirements for loss, bend radius and ruggedness, through mm wavelengths

Connecting components, boards, subsystems, and systems can be accomplished with waveguide, semi-rigid and flexible cables—each offering its own defined set of strengths and weaknesses. Challenging applications exist, however, that cannot adequately be satisfied with any of these options. One seldom considered and relatively unknown approach—electroformed cables—uniquely addresses the needs of many highly demanding applications. In contrast to a traditional cable and connector assembly, this solution integrates both the transmission line and connector to form an extremely rugged interconnect system. Produced through an electroform process, this one-piece unit offers the advantages of insertion loss performance surpassed only by waveguide, ruggedness that meets the demands of military missiles and fighter aircraft, and a bend radius that is tighter than any semi-rigid or flexible cable.

Traditional microwave interconnection systems have evolved from waveguide, to semi-rigid cables and formable cables, to flexible cables. Waveguide has distinct advantages in terms of insertion loss and power handling capabilities, but at low microwave frequencies they are unwieldy. Except in cases where high power levels must be handled, other alternatives are generally preferred. In most instances, the first choice of designers is semi-rigid cable for its low cost, connector choices, formability to a traverse circuitous path, and relative small size and ruggedness.

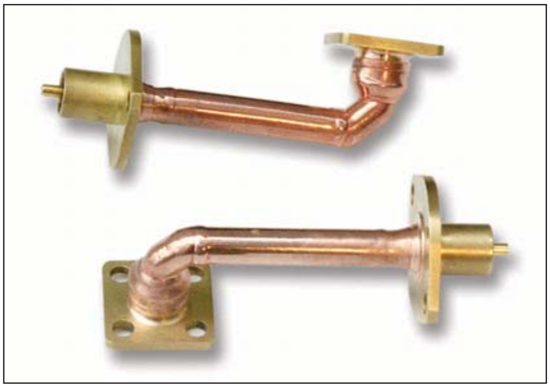


Figure 1 · Typical electroformed interconnect systems by Semflex.

The downside includes phase instability and difficulty during installation which requires 3-dimensional drawings.

Unlike its semi-rigid cousins, flexible cables do not need the same critical consideration in the design of a subsystem or system, because their inherent flexibility makes them easy to configure inside the confines of a housing. Of the three types of interconnects, flexible cables have the highest loss, although the best in this class offer respectable performance. Flexible cables may also be quite rugged, making them a favorite choice in the relatively hostile environment of test and measurement applications.

With all these choices available, special applications still exist that demand a combination of very low loss, rugged structure, tight bend radius, and high electrical and mechanical performance in harsh environmental conditions. For example, missile systems and fighter aircraft endure extraordinary hostile conditions including the stress of launch, shock and vibration, and rapid temperature cycling. In situations like these, the RF interconnects are a weak link in various on-board electronic systems, especially at the cable/connector interface.

The electroformed process implemented for cable technology by Semflex, a designer and manufacturer of microwave frequency cable and cable assemblies, was created as a solution for these applications (Figure 1). Compared to the alternatives, these interconnects are unique in both their manufacture and finished look. An electroformed cable is actually a single, seamlessly integrated unit. As a consequence, there is no solder, crimping, or other cable/connector attachment method required, virtually eliminating problems encountered at the cable/connector interface.

The evolution of the electroform process technology at Semflex began with a prime contractor requirement for a missile system employing RF systems operating in the high microwave frequencies. Since the outer enclosure of a missile is round, it conflicts with the generally square electronic subassemblies contained within it. In addition, there is limited area in which to work, so connections between modules require an interconnect system that can accommodate severely tight bends without compromising either performance or reliability. The customer had tried implementing flexible cable, but insertion loss was too high compounded with concerns that the connector would not fit with the space constraints. Semi-rigid cable was considered next, but the requisite bends were too sharp and susceptible to breakage. In addition, performance was compromised because a discontinuity was created at the point of the bend, where the distance between center conductor and shield narrowed. An electroformed approach was proposed by Semflex as a possible solution.

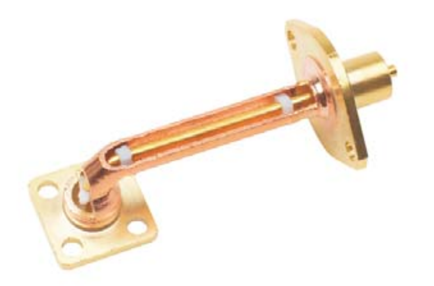


Figure 2 · The PTFE beads used to separate the center conductor from the outer shield are clearly visible in this cutaway photo.

Electroforming is not a new technology per se, it was initially used in the 1800s for making works of art and printing plates. In World War II, nickel-electroformed tooling was employed and the process was utilized in jewelry making. In electroforming, metal is electrodeposited on a mold, then the metal is separated from the mold—producing a precise replica. Because it is an additive process, it has advantages over other forming technologies. Finer geometries can be produced to tighter tolerances, and the process is essentially insensitive to temperature or humidity. The resulting parts have very low mass, are electrically conductive, rigid, and essentially unbreakable. The 3-dimensional nature of electroforming allows very tight tolerances to be maintained.

The molds can be made from stainless steel, aluminum, polymers, and waxes. Once the initial set-up process is completed, it is relatively easy and inexpensive to produce additional copies of the electroformed product. Electroforming has the inherent advantage of being extremely precise, particularly with computer-aided selection of deposit thickness, which lends it well to creation of products such as RF interconnect systems. Electroforming also allows a range of metal choices, including nickel, silver and gold. Its exceptional thermal and electrical conductivity add to its advantages.

Over time, Semflex has perfected an electroforming process for the manufacture of high reliability interconnects. The bent center conductor with the insulating PTFE beads (for support) is placed in the mold and injected with wax. A silver coating is applied over the cooled wax surface and copper is "grown" onto the wax, with most of the brass connector masked off. The wax is then evacuated, leaving a rigid structure in the desired shape. Figure 2 shows the PTFE spacers that separate the center conductor from the outer shield.

Advantages of Electroformed Cable Assemblies

• *Unmatched strength:* The electroform process produces an assembly that is extraordinarily strong, a key strength of the process for this application. The resulting products meet or exceed every military requirement for shock and vibration.

• *Extremely narrow bends:* The process allows tighter bends that are more extreme than those achieved with semi-rigid or flexible cable.

• *Low dielectric constant:* The goal of every cable assembly is to have a dielectric constant as close as possible to that of air (1.0). Including the effect of the PTFE spacers, the dielectric constant of typical Semflex electroformed assemblies is 1.001, versus 2.1 for a cable with a solid-PTFE or other solid dielectrics.

• *Elimination of solder:* The connector is not soldered to the cable for most of the assemblies, so there are no issues with flux and outgassing, making it suitable for operation in space environments.

• *Low insertion loss:* For a given set of specifications, insertion loss is lower than any other type of cable. Only waveguide has lower loss.

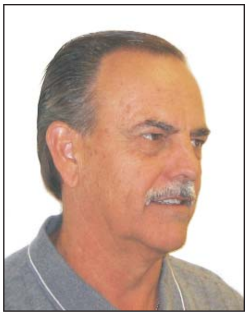
• *Broad operating frequency:* While the operating frequency range of typical applications is usually not terribly broad, the cable itself can operate from 2 to 67 GHz, with superior performance characteristics throughout this range. Frequency range is limited only by available connectors.

- *Superior phase stability:* Since the dielectric is air, there are no elements present that affect phase stability, even over broad temperature ranges.
- *Lightweight:* The precision of the electroform process allows wall sizes to be thinner, which produces a very light product without reducing ruggedness.
- *Hermeticity:* The assembly can be made hermetic by using a glass feedthrough.

The specifications for electroformed products vary with the specific customer requirement. However, the performance of the product can be demonstrated when comparing it to alternatives, given a specific set of requirements. This technology approach is not intended for applications that can be served by the variety of semi-rigid and flexible cables available on the market. However, when the extreme ruggedness, tight bend radius, and very low insertion loss are required, electroformed assemblies present an excellent alternative, perhaps the only one.

Interested readers may contact Semflex by telephone at 800-778-4401, by fax at 480-985-0334, or see their Web site at www.semflex.com.

Author Information



Bob Thiele is the Vice President of Engineering, New Product Development, for Semflex, Inc., a Stratos International Company. Semflex designs and manufactures high-performance microwave and RF coaxial cable and customer cable assemblies for the military, aerospace, commercial and test instrumentation markets worldwide. Bob founded Semflex in 1979, and served as President and CEO until assuming his current responsibilities in 1994. He has over 30 years of experience in high frequency connectivity design and is consistently involved in the daily activities of design, prototyping and testing of new products. Bob received his Bachelor of Science degree from California State University, Fullerton.