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A FIBER OPTIC CABLE COMMUNICATIONS LINK FOR TETHERED REMOTELY CONTROLLED SUBMERSIBLES

M. McCord

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

A fiber optic communication link that would be tolerant of electromagnetic interference and suitable for use with tethered, remotely controlled submersibles is described and a test program recommended.

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ILLUSTRATIONS

SUMMARY

PURPOSE

This document presents a concept for a fiber optical cable communication link (FOCL) suitable for tethered, remotely controlled submersibles.

BACKGROUND

FOCL was conceived as a possible electromagnetic interference (EMI) tolerant alternative to the EMI susceptible electromechanical cable communication link of the Mine Neutralization System (MNS) Advanced Developmental Model (ADM).

DESCRIPTION

The envisioned FOCL consists of an electro-optical/mechanical cable, a cable handling and storage unit, a pair of optical interface units, and a pair of signal processing units. Functionally, FOCL is capable of transmitting three-phase electrical power and four telemetry signals (two narrowband signals and two wideband television-quality signals) over a composite electro-optical/mechanical cable.

RECOMMENDATIONS

1. The conceived FOCL is inherently EMI tolerant by virtue of its optically isolated interfaces, and thus represents a potential solution to the EMI susceptibility of the MNS. Also, once developed, FOCL will be highly adaptable to many other applications.

2. Although many of the envisioned FOCL subsystems have been developed and evaluated independently, the FOCL concept as a system has not been evaluated. Therefore, FOCL will require the conduct of system performance evaluation and analysis. The recommended approach for the conduct of system performance evaluation and analysis is to develop and evaluate an operational model of FOCL.

INTRODUCTION

Advanced naval shipborne weapon systems employ a large number of electronic sensors, probes, and other electrical devices. Sometimes these systems are required to operate simultaneously and always in near proximity of each other. The performance of these electronic systems must not be degraded by electromagnetic interference (EMI) nor can the EMI signature of a particular system be allowed to degrade the performance of other systems. That is, all systems must be electromagnetically compatible (EMC).

Tests conducted on the Mine Neutralization System Advanced Development Model indicated that the system is susceptible to EMI. Furthermore, the tests indicated that the primary electromagnetic (EM) intrusion points are: (1) along the tethered cable, (2) at the low-level signal origination and reception points, and (3) at the tether cable retrieval and storage unit. All of these EM intrusion points are within the MNS/ADM power and communication cable link. Since a highly desirable characteristic for future MNS units is EMI resistance, the Naval Ocean Systems Center (NOSC) conducted a brief study (reference 1) to evaluate the feasibility of an EMI-resistant cable communication link suitable for tethered submersibles. The study concluded that an optical cable communication link would alleviate the EMI problems experienced by the MNS/ADM. Moreover, the results of the study indicated that an optical cable communication link also is superior to the traditional electromechanical cable link in terms of mechanical and electrical characteristics, data transfer characteristics, and shipboard compatibility. Furthermore, a communication cable link of this caliber would be highly useful in a wide range of naval applications. Among these applications are:

- towed sonars and sensors
- remote underwater surveillance platforms
- underwater test ranges
- submarine cables

This document presents a concept for a fiber optic communication cable link (FOCL) suitable for tethered, remotely controlled submersibles, such as the MNS.

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1. I. Lemaire, NOSC memo ser 521/99-79, subj: "MNS Fiber Optic Link Investigation," 18 July 1979.

CONCEPTUAL DESCRIPTION

GENERAL DESCRIPTION

A conceptual block diagram of FOCL is shown in Figure 1. The primary components of FOCL are:

- an electro-optical/mechanical cable
- a pair of optical interface units
- a cable handling and storage unit
- a pair of signal processing units

Spatially, FOCL is divided into two sections, the vehicle section and control station section. The vehicle section consists of a signal processing unit, an optical interface unit, and an electro-optical/mechanical cable. The control station section consists of a cable handling and storage unit, an optical interface unit, and a signal processing unit. Figures 2 and 3 are detailed diagrams of the vehicle section and the control station section, respectively.

Functionally, FOCL will be capable of transmitting three-phase electrical power and four telemetry signals (two narrowband signals and two wideband television-quality signals). The three-phase power will be transmitted from a power source, located in the vicinity of the vehicle control station, directly to the vehicle via three designated copper alloy power conductors located in the electro-optical/mechanical cable. Following conditioning, the four telemetry signals will be optically encoded and then transmitted via three fiber optic elements, also located in the electro-optical/mechanical cable, to and from the control station and vehicle as required.

SPECIFIC DESCRIPTION

The following paragraphs present a conceptual description of each primary FOCL component.

Signal Processing Units

The conceived FOCL will employ two signal processing units (SPUs), a vehicle signal processing unit, and a control station signal processing unit, as shown in Figures 2 and 3. Functionally, the signal processing units are microcomputers which will act as signal interface buffers between the command units, the sensor data acquisition unit, and optical interface units. Referring to Figure 2, it is envisioned that the vehicle SPU will convert "raw" sensor signals, obtained from the vehicle sensor data acquisition unit, into signals that are compatible with the vehicle optical interface unit. The vehicle SPU will also convert signals transmitted from the control station command unit into signals that can be utilized by the vehicle command unit.

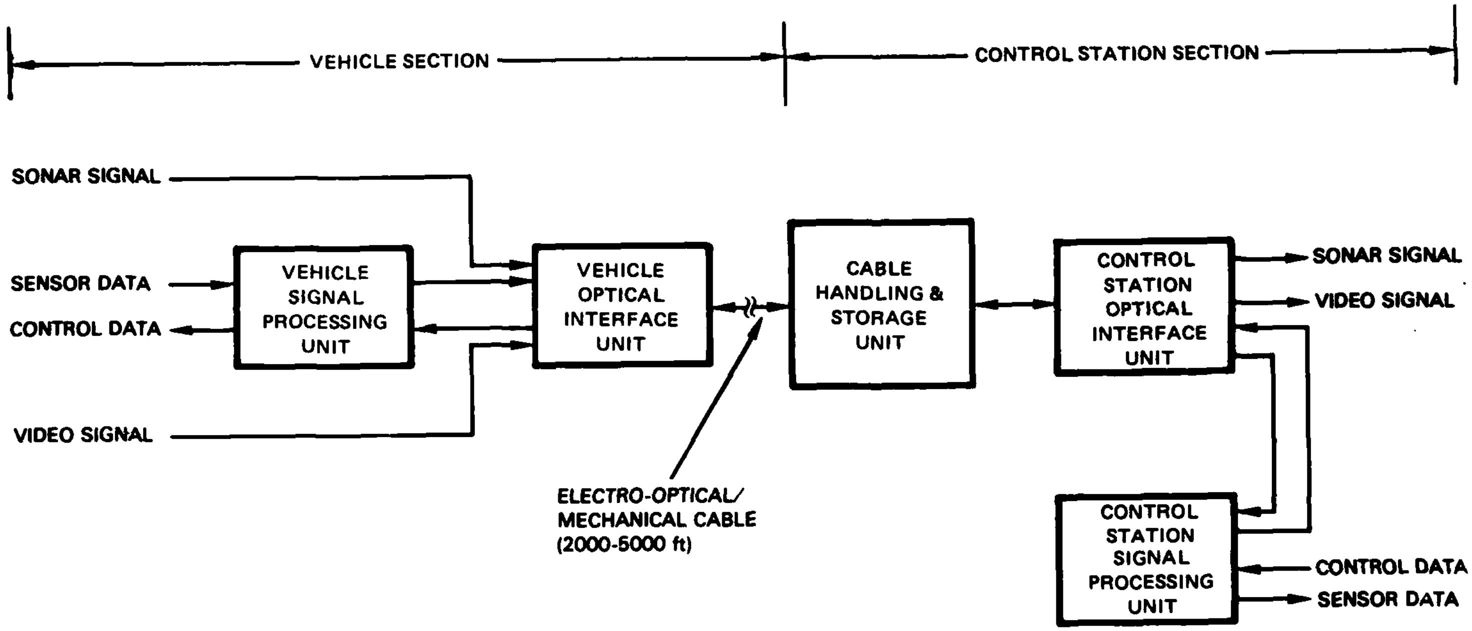

Figure 1. Conceptual Block Diagram of Fiber Optic Cable Communication Link (FOCL).

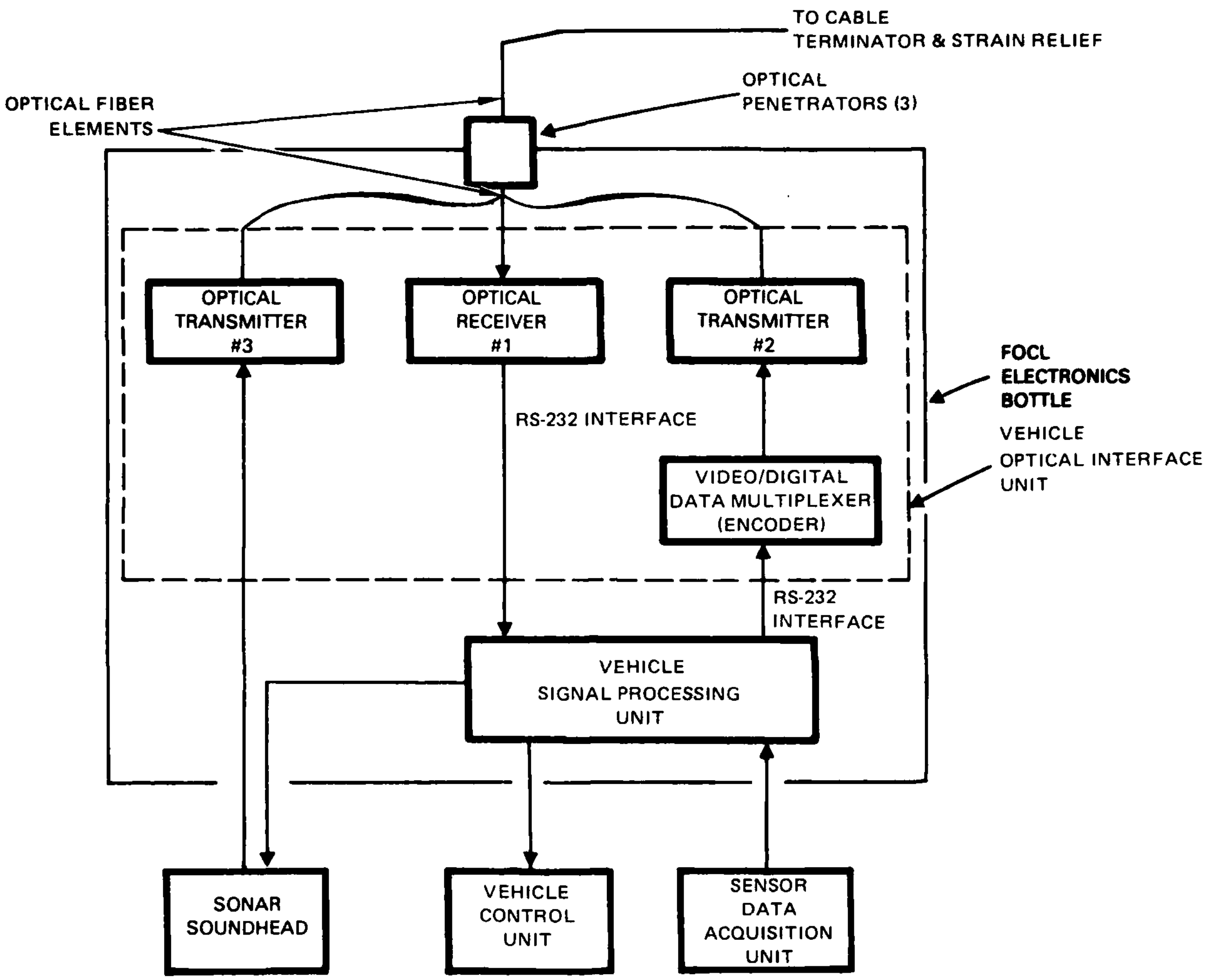

Figure 2. Conceptual Diagram of FOCL Vehicle Section.

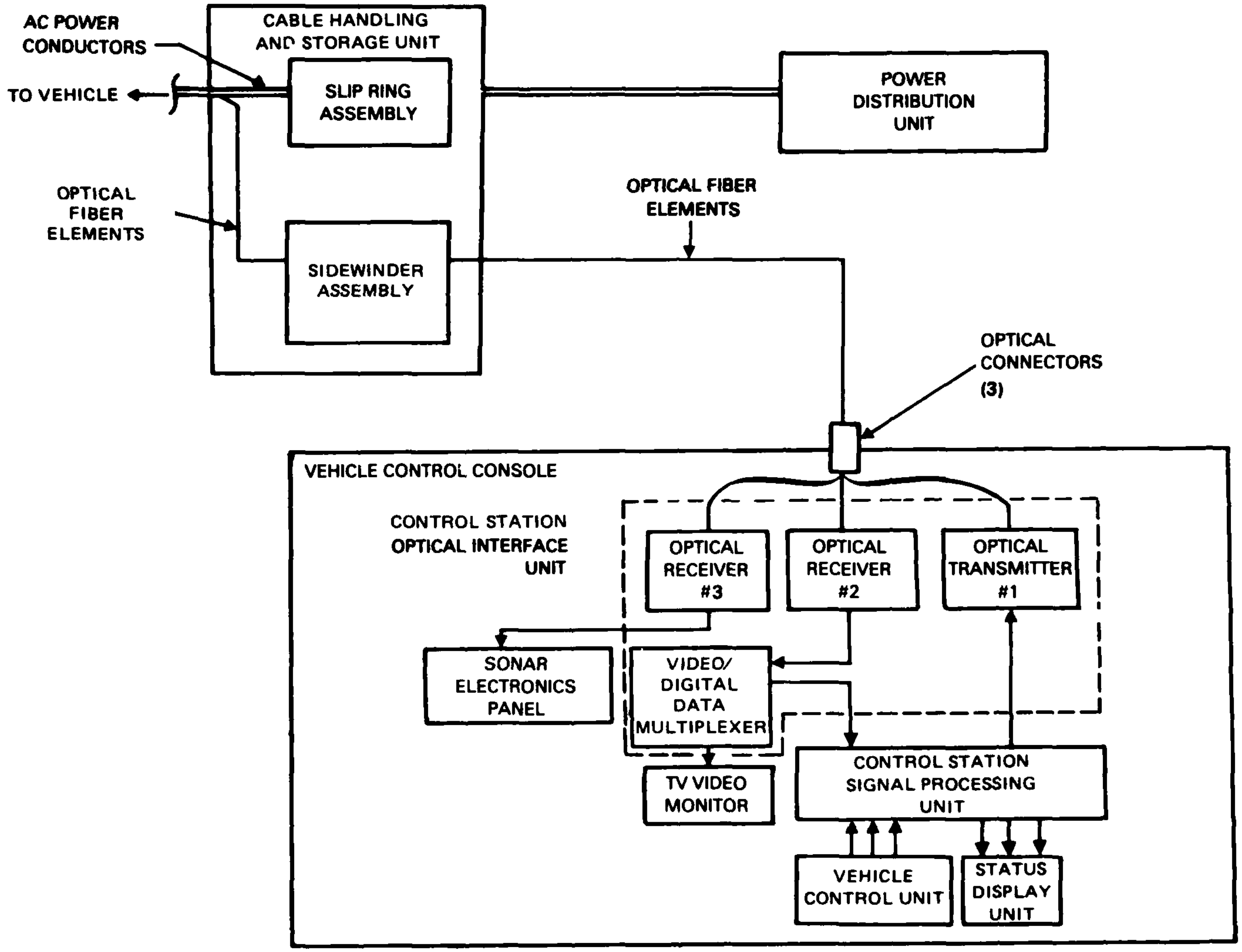

Figure 3. Conceptual Diagram of FOCL Control Station Section.

In a manner similar to that of the vehicle SPU, the control SPU will act as a signal interface for the control station command unit, the status display unit, and control station optical interface unit.

Optical Interface Units

The FOCL optical interfaces will consist of a vehicle optical interface unit and a control station optical interface unit, as illustrated in Figures 2 and 3. The units will be composed of three reciprocal optical transmitter/ receiver pairs, recently developed by NOSC, called "Pulse Frequency Modulation (PFM) optical transmission links." Each PFM optical transmission link is capable of transmitting a 4.5-MHz-bandwidth signal over a single fiber optic element. A detailed description and principle of operation of the PFM optical transmission link are given in reference 2.

The optical interface units will perform two critical functions. First, they will condition the FOCL telemetry signals for efficient transmission over an optical link. Secondly, they will function as optical transmitters and receivers.

Operationally, the optical interface units will be capable of optically encoding and transmitting four signals over three optical fiber elements. The four signals are a 4.5-MHz-bandwidth RS-170 television signal, a 4.5-MHz-bandwidth sonar signal, and two asynchronous RS-232 interface-compatible digital signals (one vehicle-to-control-station signal and one control-station-to-vehicle signal). The control-station-to-vehicle digital signal will be optically encoded, as illustrated in Figure 3, and then transmitted to the vehicle over fiber optic element 1. In a similar manner, the sonar signal will be optically encoded and transmitted over fiber optic element 3. The television signal and the vehicle-to-control-station digital signal will be transmitted simultaneously over fiber optic element 2 using a device, recently developed by NOSC, called a video/digital data multiplexer (reference 3). Basically, the video/digital data multiplexer will pulse position modulate (PPM) the digital signal onto the horizontal sync pulses of the television signal to form a "composite signal." The composite signal will then be optically encoded and transmitted to the control station, as illustrated in Figure 2. At the control station, the optical representation of the composite signal is converted back to an electrical signal and is then pulse position demodulated (PPD'd) into the original separate television signal and digital signal. Figure 4 is a photograph of the NOSC prototype video/digital data multiplexer and a single PFM optical transmission link.

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2. S.J. Cowen, "Fiber Optic Video Transmission System Employing Pulse Frequency Modulation," OCEANS '79, Sept. 1979, pp. 2253-259.

3. A. Arriola, NOSC memo ser 5213/25-80, subj: Video/Data Multiplexer Demonstration System," 5 Mar 1980.

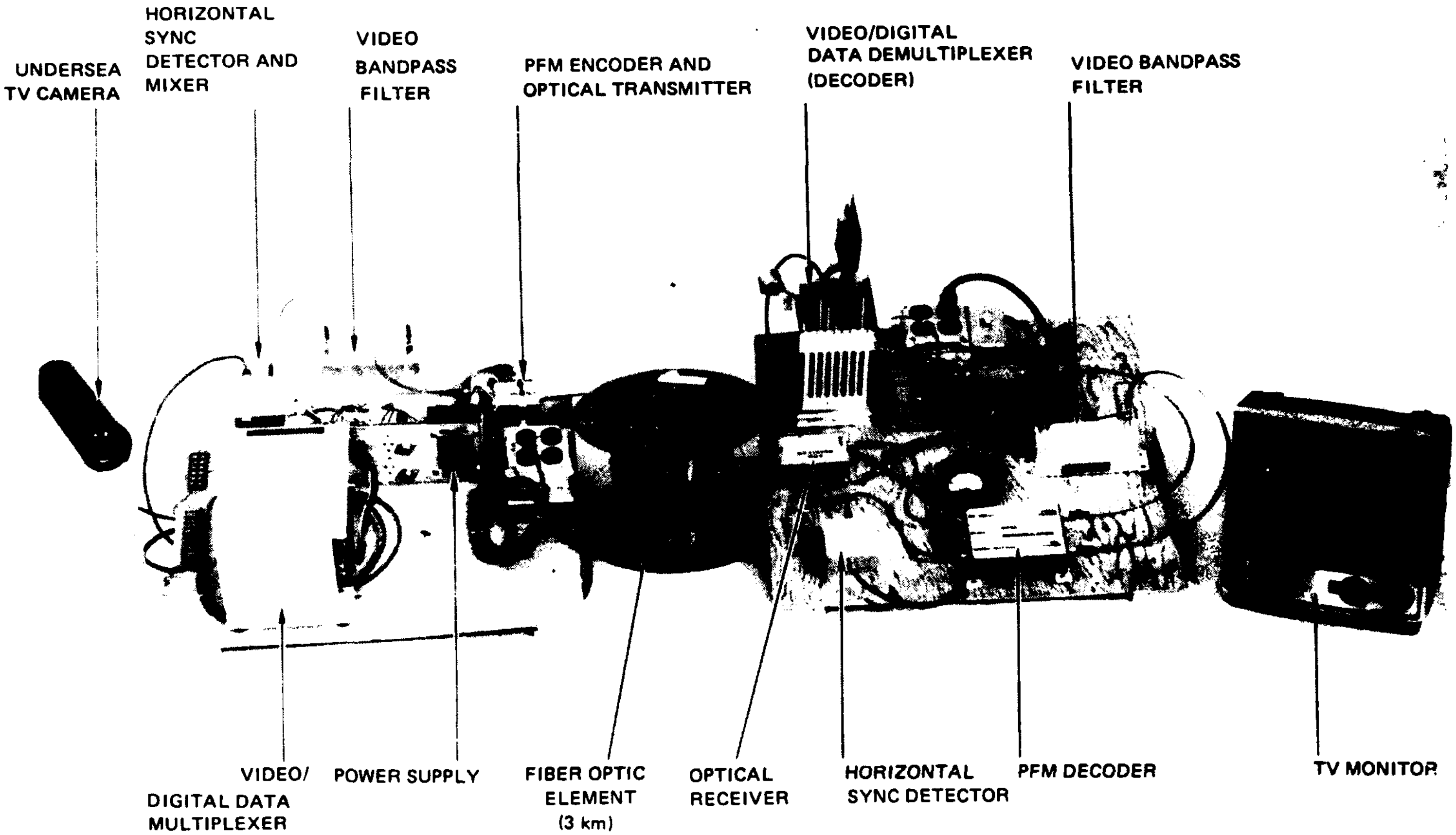

Figure 4. The NOSC Prototype Video/Digital Data Multiplexer and a Single PFM Optical Transmission Link.

Electro-Optical/Mechanical Cable

The FOCL electro-mechanical cable will perform the critical function of acting as the electrical power transfer channel and the telemetry communication channel between the control station and vehicle. Functionally, the cable will be capable of transmitting three-phase power and three optical signals. The three-phase power will be transmitted by three designated copper alloy conductors. The optical signals will be transmitted via three fiber optic elements.

The design for the FOCL cable will be taken from the design for a prototype electro-optical/mechanical cable recently fabricated and tested by NOSC. A cross-sectional layout of the NOSC prototype cable is shown in Figure 5. Briefly, the NOSC prototype electro-optical/mechanical cable contains three ruggedized optical fibers, three annealed copper alloy #20AWG power conductors, and a 978-finish KEVLAR 49 fiber rope strength member. The cable also contains low-density void fillers, lubricants, and bonding materials. The cable's outer protective jacket is a pressure-extruded low-density polyethylene plastic. The nominal outer diameter of the cable is 0.66 in. A detailed description of the cable is given in reference 4.

The NOSC prototype cable has been subjected to a series of tests, conducted by Tension Member Technology, Inc., designed to evaluate the performance of the cable under simulated field service conditions. The results of these tests are documented in reference 5. However, as a point of primary interest, the prototype cable:

1) Successfully completed 50,000 bending cycles at a constant tension of 800 ft-lb over a 28.0-in.-diameter sheave.

2) Exhibited a breaking strength in excess of 6,000 ft-lb.

Cable Handling and Storage Unit

FOCL will utilize a standard shipboard winch equipped with a slip-ring assembly for general cable handling and storage. However, a "sidewinder assembly" will be attached to the winch for the specific purpose of "handling" the fiber optic elements. A sidewinder assembly is a device whose primary function is identical to that of a slip-ring assembly. That is, a sidewinder, when attached to a winch, will allow the paying out and retrieval of an electrical cable without allowing axial cable twisting and still maintaining electrical continuity. But unlike the slip-ring assembly, the sidewinder assembly also permits continuous, non-interrupted (no connectors, brushes, liquid conductors, etc.) cable continuity. Thus, in the case of FOCL, the

4. A.R. Waltz, "Specifications for Electro-Optical/Mechanical Umbilical Cable for a Remote Controlled Vehicle," 1978 (unpublished).

5. J.A. Walther and P.T. Gibson, Tension Member Technology, Inc., Final Report on Testing of Electro-Opto-Mechanical Cables; NOSC Contract N66001-80-M-1682; 8 May 1980.

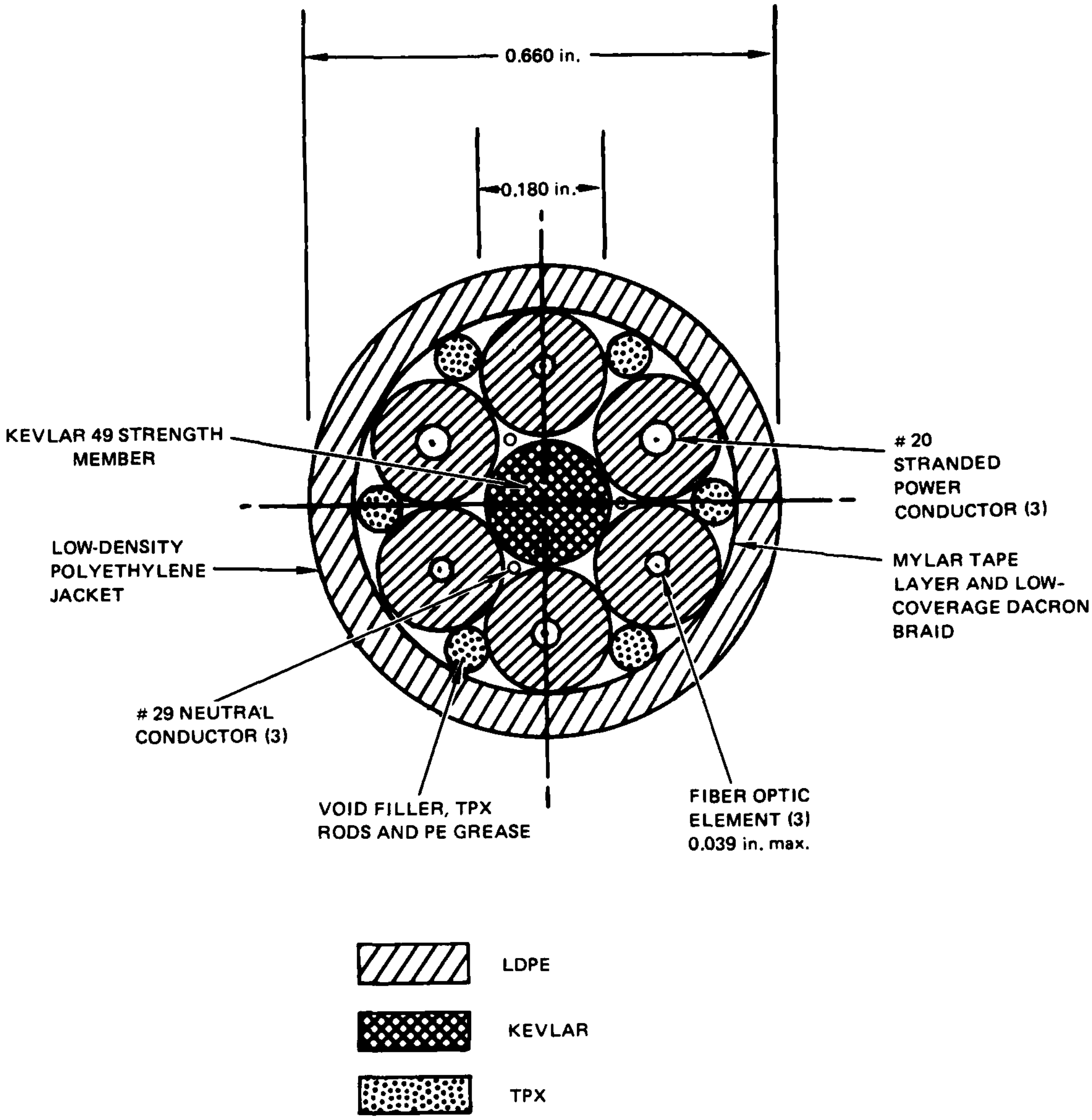

Figure 5. Cable Cross Section.

addition of a sidewinder assembly to the shipboard winch will allow the paying out and retrieval of the electro-optical/mechanical cable by a winch while continuous connection of the fiber optic elements to control station equipment is maintained.

For FOCL, it is envisioned that the sidewinder assembly will be mounted on the shipboard winch axially to the slip-ring assembly, as illustrated in Figure 6. The electro-optical/mechanical cable will be mounted on the shipboard winch as required. The fiber optic elements and the power conductors will be extracted from the electro-optical/mechanical cable at the slip ring assembly. The power conductors will then be routed to the slip ring assembly and the fiber optic elements will be routed to the sidewinder assembly as shown in Figure 3.

TECHNICAL RISKS

The concept presented in this report envisions use of several NOSC-developed prototypes, specifically, the NOSC-developed PFM optical transmission link, electro-optical/mechanical cable, and video/data multiplexer. The rationale for using NOSC prototypes is that their designs, fabrication techniques, and performance are well documented. Consequently, the technical risks associated with subsystem development will be reduced. However, system engineering risks will not be reduced. For example, the NOSC prototypes were developed independent of each other and thus lack design interface continuity. Also, the storage, paying out, and retrieval of fiber optic elements via a sidewinder device has not been evaluated. Furthermore, termination and strain relief interfaces for the electro-optical/mechanical cable also have not been investigated.

The traditional means of reducing, or at least defining, system engineering risks is to develop and evaluate an operational model of the system. Therefore, it is recommended that a prototype FOCL System be developed for evaluation. Moreover, since the MNS represents a near-term application of the FOCL System, it is also recommended that the prototype FOCL be installed and evaluated on a MNS EDM unit.

CONCLUSIONS

The FOCL design conceived is inherently EMI tolerant by virtue of its optically isolated interfaces and thus represents a potential solution to the EMI susceptibility of the MNS. Also, once developed, FOCL will be highly adaptable to many other applications.

Although many of the contemplated FOCL subsystems have been developed and evaluated independently, the FOCL concept as a system has not been evaluated. Therefore, FOCL will require system performance evaluation and analysis. The recommended approach for such testing is to develop and evaluate an operational model of FOCL.

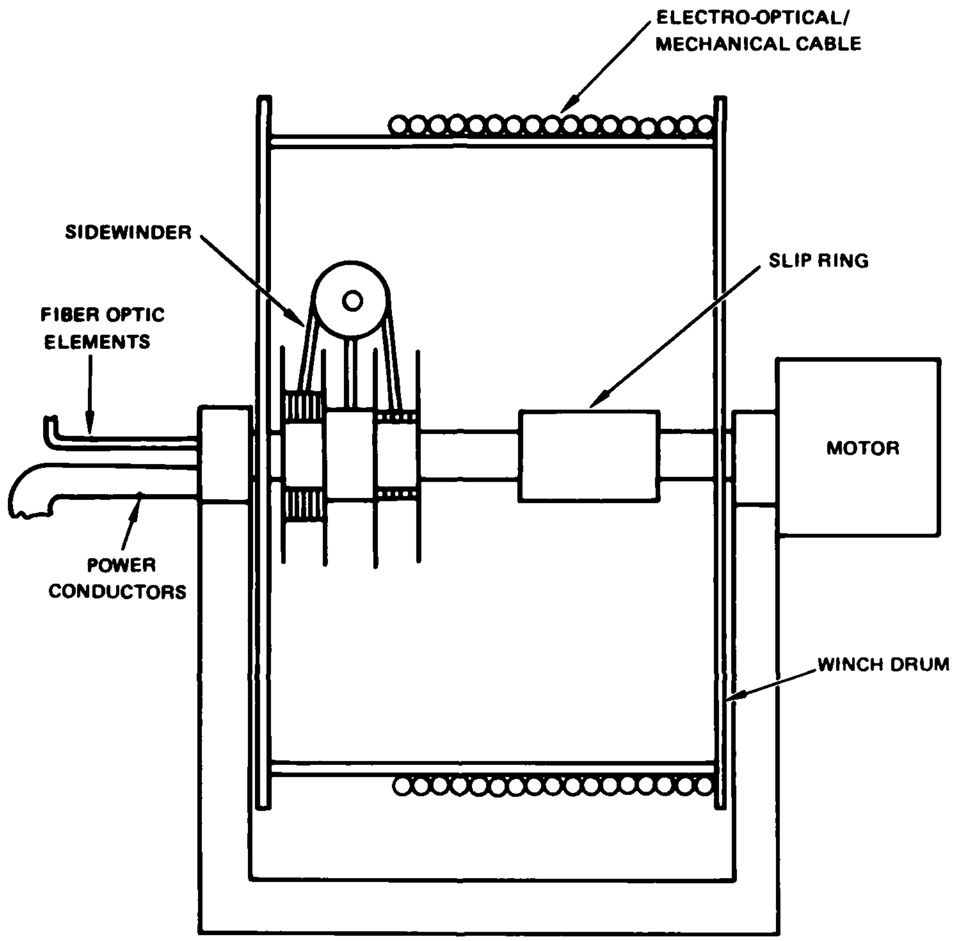

Figure 6. Shipboard cable storage and handling winch concept for FOCL.

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2. S.J. Cowen, "Fiber Optic Video Transmission System Employing Pulse Frequency Modulation," OCEANS '79, Sept. 1979, pp. 2253-259.

3. A. Arriola, NOSC memo ser 5213/25-80, subj: Video/Data Multiplexer Demonstration System," 5 Mar 1980.

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