FIBER OPTICS FOR TRAINER APPLICATIONS

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ABSTRACT

A new era is upon us; down with copper wire cable proliferation (Figure 1); the age of cool bright optical communications is here. Presently, there are large performance advantages (bandwidth, noise immunity, signal attenuation, size, weight, and total electrical isolation) associated with fiber optics data communications. In the very near future, there will also be cost advantages.

This paper gives an introduction to fiber optics and shows how to apply this exciting technology to trainers for RESOURCE CONSERVATION THROUGH SIMULATION.

INTRODUCTION

In recent years, fiber optics technology has become a very promising candidate to replace metallic wire conductors. The stimuli for this advancement are the recent reduction of signal attenuation of fiber optics and the rapid advances in semiconductor light sources and photodetectors. This paper will introduce fiber optics technology and describe trainer applications.

Recent predictions on fiber optics show that they will provide the largest growth area in electronics since the integrated circuit. It is hoped that this paper will serve to stimulate systems' users and designers to consider the potential advantages of fiber optics and to evaluate this technology as it applies to their systems requirements.

The following developments are taking place in the fiber optic field:

1. All telephone interswitching center communications of under five kilometers are being converted to fiber optics.
2. Cable TV systems in the U.S., England, Germany, and Japan are using fiber optics.
3. The Navy has two ships at sea with fiber optic systems.
4. The Navy converted and flew an A7E aircraft with fiber optic fire control system with the following results:

	WIRE	FIBER OPTICS
No. of Cables	302	13
Total Length	4832 Ft.	260 Ft.
Cable & Connector Weight	87 lbs.	3.6 lbs.
Parts Cost	9.7 K	1.1 K

FIBER OPTIC JARGON

The following fiber optic terms will be used throughout the paper:

1. TYPICAL F/O SYSTEM

A typical fiber optic system consists of three elements:

(a) A transmitter that converts the electrical signals into light energy signals. The antenna or energy projection device is usually a LED or Laser Diode (Gallium Arsenide Technology).

(b) The fiber light guide that carries the optical energy.

(c) A receiver that converts the light energy signal into a useful electrical signal. The detector or energy absorption device is usually a PIN diode or Avalanche detector (silicon technology).

2. FIBER CABLE

The principle of transmitting light energy requires that the light stay within the fiber cable (waveguide). This is accomplished by having the index of refraction different between the center and outside of the cable (total internal reflection). When the inside tube contains one index

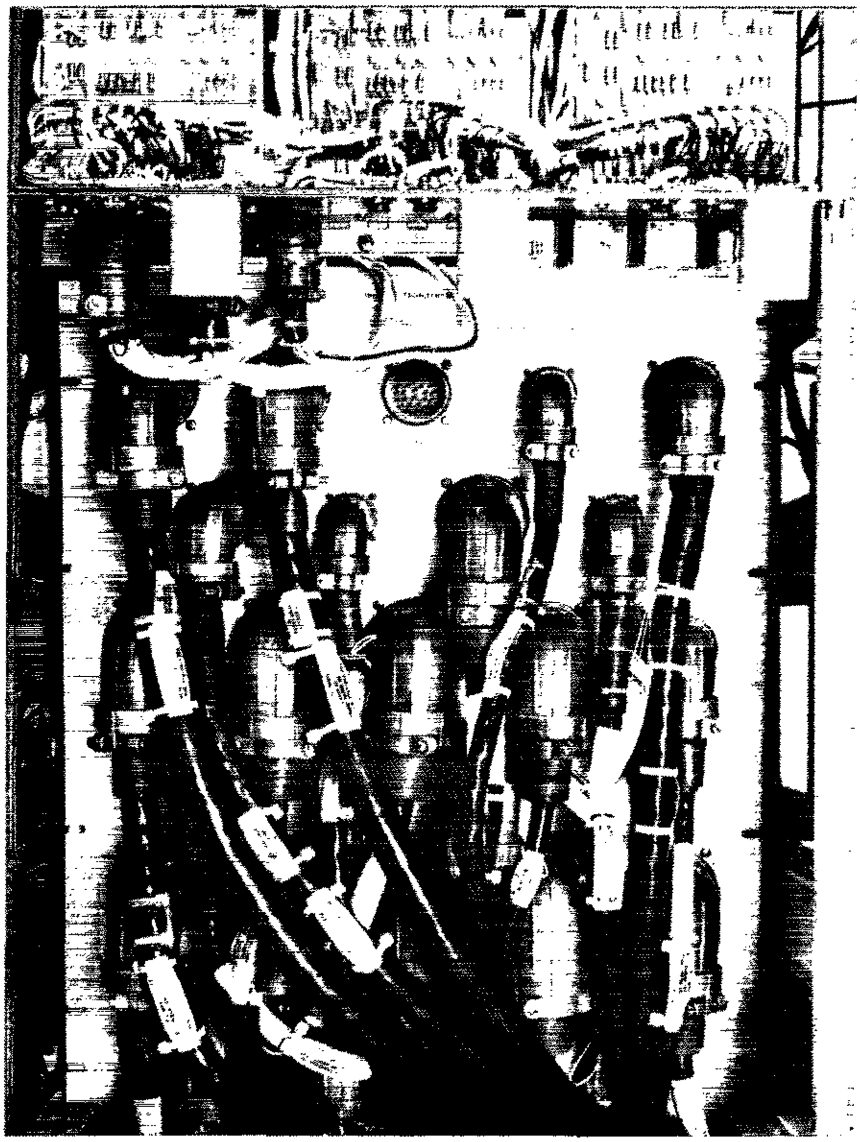

Figure 1. Conventional Cabling Pollution

	FIBER OPTICS	COAX
LOW COST	X	X
300° C TEMPERATURE	(GLASS)	X
VIBRATION	X	X
LOW CROSS TALK	X	X
NO CROSS TALK	X	
RFI, EMI, NOISE IMMUNE	X	
TOTAL ELECTRICAL ISOLATION	X	
NO SPARK (FIRE)	X	
NO SHORT DISABLING	X	
NO RINGING	X	
1000°C TEMPERATURE	(GLASS)	
EMP IMMUNE	X	
NO CONTACT UNRELIABILITY	X	
SIGNAL BANDWIDTH	$>$1 GHZ	$>$20 MHZ
POWER TRANSMISSION		X
PRODUCTION AND SUPPORT ENGINEERING		X
NEW TECHNOLOGY	X	
LOSS IN CONNECTIONS AND SPLICES	X	

Figure 2. Comparison of Cable Features

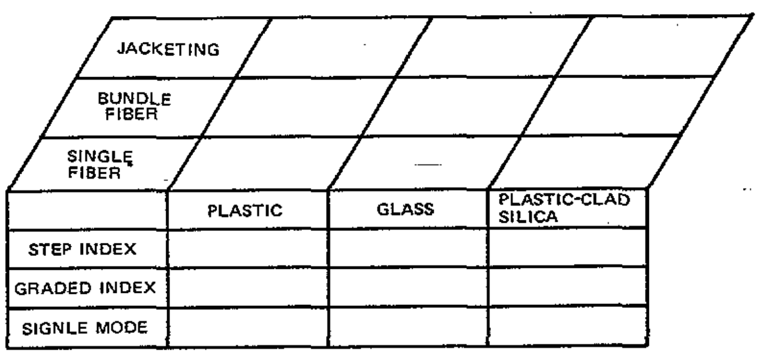

Figure 3. Fiber Optic Cable Selection Tradeoffs

and is surrounded by an outer tube of lower index, we have a step index fiber. When the index varies linearly from the center to the outer edge, we have a graded index fiber.

The following three classes of cable are presently being produced today:

	PLASTIC	GLASS	PLASTIC CLAD SILICA
Cost	Low	High	Medium
Loss	Mid-High	Low	Low
Handling	Excellent	Poor	Good
Environmental	Poor	Good	Good

3. SINGLE FIBER

One single strand of fiber optic cable enclosed in a protective jacketing. The jacketing is only for environmental protection since the fiber keeps the light energy wholly within its structure.

4. BUNDLE FIBER

A multiple strand fiber optic cable containing (7, 19, etc.) fibers each carrying the same light energy and enclosed within a protective jacketing.

5. FIBER LOSS

The amount of light energy loss in the fiber cable primarily caused by scattering and absorption. Cables are usually graded into three categories:

Low Loss ($<$10 dB/KM), Medium Loss (10 dB$<$L$<$100 dB/KM), and High Loss (100 dB$<$L$<$1000 dB/KM)

6. CONNECTOR/SPLICE LOSS

In contrast to coax systems, every connection/splice causes light energy loss primarily due to misalignment, reflection, and absorption. Present day connectors introduce three to six dB of loss depending on whether they are single fiber or bundle connectors. Also, connector availability is very suspect at the present time, but it is bound to improve. Laboratory splices have been made in the .1 to .2 dB range, but there is a great need for field repair methods and equipment.

7. RECEIVER

A receiver circuit accepts light in the 10 to 100 nanowatt range and produces TTL compatible outputs (0-5V).

8. TRANSMITTER

A transmitter circuit accepts TTL level inputs and produces one to ten milliwatts of light power out of an LED.

9. "T" CONNECTOR

This is a passive optical tap that allows energy to be extracted from a fiber optic cable and allows optical energy to be interjected into the fiber optic cable from a receiver/transmitter (R/T) port.

10. RADIAL ARM COUPLER

This is a passive optical device that allows the light energy from one fiber optic cable to be divided into an optical signal on many fiber optic cables. The following two types of radial arm couplers are presently in use today:

a. Reflective: A reflective radial arm coupler contains a mixing rod and a mirror. Every R/T port is connected to the coupler by only one fiber. Light energy coming from one R/T into the coupler is reflected back on the fiber cables to all other R/T ports.

b. Transmissive: A transmissive radial arm coupler contains an input port of fibers, a mixing rod, and an output port of fibers. The light signal from any R/T is thus sent to all R/T's by the coupler. This type of radial arm coupler is the simplest to mechanize and presently the lowest in cost.

FIBER OPTIC ADVANTAGES

The recent announcements of fiber optic cable TV systems in New York, London, and Tokyo along with the first operational telephone system in Chicago (Bell) and Long Beach (GTE) should convince doubters that fiber optic technology is here today.

Why should one be interested in fiber optics systems for trainers? The major reasons are bandwidth and noise immunity.

Figure 2 tabulates the comparative features of fiber optics, and coax. Each line on the chart endeavors to show a fair comparison. For low cost, the common factors are the same cable size, flexibility, equivalent bandwidth, and manufacturing quality.

Fiber optics or coax offer a fairly even choice in the first four categories. If one wants a low crosstalk or no crosstalk (that is, no measurable crosstalk between adjacent fibers in a fiber bundle), one would want to use fiber optics. Since there is no crosstalk between adjacent fibers, there is certainly no crosstalk between adjacent fiber cables.

Fiber optics, being made of a dielectric, provides ideal RFI/EMI noise immunity. They do not pickup, nor do they radiate any signal information. Fiber optics also provides total electrical isolation between the sending and receiving terminals, eliminating any common ground and the problems that are associated with common grounds (voltage offsets, ground currents, ground noise, pickup, etc.). There are no spark or fire hazards with fiber optics should the fiber optics be damaged. There is no local secondary damage incurred because no sparking, heat, or electrical energy dissipation of any sort takes place. There can be no short circuits or circuit-loading reflections back to the terminal equipment if a fiber optic cable should be damaged. In wire systems, the damage to a cable may cause reflected damage into the terminal circuits by shorting, grounding, or dangerous potentials and currents in the wires. The fibers do not conduct electrical current and, thus, eliminates this problem.

Fiber optics have EMP immunity for the same reason — they have RFI/EMI immunity. Wire systems suffer from connector discontinuity problems because of the need for good physical contact connector interfaces for signal transfer. Proper polishing of the optical interface between light source and the fiber optic bundle provides a signal connection requiring *no physical contact*. The light energy signal passes through the small air gap between the devices and the end of the fiber optic bundle. Grits and opaque materials, however, decrease transmission or damage connector surfaces if proper procedures are ignored. Temperatures up to 1,000° C may be withstood by certain glass systems. Most present fibers are stable well beyond 300° C.

Assuming an acceptable fiber loss factor in the range of 50 dB/km, one finds a 200 megahertz limit with fiber optics for a 300 meter length. Coax, according to handbook data, is limited to 20 megahertz for the same cable size and length, and a twisted wire pair to 1 megahertz. Fiber optic systems with bandwidths over 100 megahertz should be considered laboratory systems at present, and not quite ready for deployment. Potential signal bandwidth with single mode fibers is calculated to be above 1 gigahertz.

FIBER OPTIC CABLE

The selection of a fiber optic is very *important*. However, one is immediately faced with a number of decisions, claims, and counterclaims. In reality, the application will drive the selection of the cable used, and that in turn drives the selection of light energy sources, detectors, and electronics. Figure 3 is a three-dimensional representation of the trade offs required in selecting a fiber optic cable.

ELECTRONICS

A rapid evolution is taking place in the electronics associated with fiber optic systems. Up to today, the high cost of fiber optic cable and discrete component designs have been the driving factors in system sensitivity analysis. Presently, however, we are in the second step of the evolution where the electronics is being packaged in hybrid and monolithic form. Finally, we will see totally integrated sources, detectors, and all electronics in one DIP package. Figure 4 depicts this evolutionary process.

Fiber optic technology is thus moving from the "scab on" (mounted external to the existing equipment) to the equipment design philosophy. To be cost effective, fiber optics must be the first design approach and not a backup.

TRAINER SYSTEM APPLICATIONS

If we look at a modern trainer like Honeywell's Sonar Operator Trainer or Device 14E27, we see two areas of application for fiber optics.

First, we need intra-cabinet "point-to-point" data links (Figure 4). Because our systems contain totally modular, distributed, self-diagnosed, and stand-above cabinets; the ground isolation, noise immunity, bandwidth, and elimination of copper make fiber optics a *cost effective solution today*. Imagine a large digital system generating sonar waveforms which are to be converted to low-level analog signals. These signals will then be used to stimulate operational sonar hardware at the low-level hydrophone inputs. Also, the sonars contain spectrum analysis equipment which are very sensitive to coherent noise. Historically, ground noise in a system like this has been a constant source of trouble. Fiber optics communications has no common or ground return.

A number of ways have been discovered for taking advantage of the fiber optic characteristics for multiple channel communications. As we now know, there is no measurable crosstalk between adjacent fibers in a bundle, and

Figure 4. Time Line of Fiber Optics Development

thus, no crosstalk between groups of fibers. The fiber optic bundle may thus be subdivided with each group of fibers being a separate, parallel, channel. This concept may be extended to a single fiber per channel if one can afford to give up the redundancy in a group of fibers.

Light sources with different wavelength characteristics (colors) may be employed to add to the data capacity of fiber optics. This wavelength (or carrier frequency) "multiplexing" allows several channels to be carried on a fiber bundle, subgroup of fibers, or even on single fibers. Practical limits are presently about five colors in the range from visible red (~6500A) to the near infrared (~9300A). Various combinations of all three "multiplexing" techniques may be used to enhance greatly the data capacity of fiber optics.

Second, we need multiplexed data busses for microprocessor based distributed systems that are being developed today. Fiber optic data bus developments are the biggest R&D areas today. Figure 5 shows the "T" and "star" data bus configurations being developed today. The "T" system is the most like a coax system, but it has two major drawbacks: First, a passive system sustains so much loss per port that eight taps is about maximum; and second, if repeaters are placed at the taps to overcome signal loss, the system reliability is reduced significantly.

The "star" uses a radial arm coupler which is being developed by many companies today. This concept requires low-cost fiber and low signal loss connectors. Both requirements are becoming facts today. In the next few years, we will see this type of data bus predominate because it overcomes the problems associated with the "T" coupler.

FUTURE

The path is very clear and fiber optics is in wide usage. There is enough performance/cost/environmental data to perform systems and product studies.

As we view the situation:

1. Fiber costs will decrease steadily. Monolithic and integrated optical/electronic modules are in the product development stage and will provide low cost systems.

2. Fiber optics will reduce the cost of trainer systems by allowing wider band data transmission with total electrical noise immunity.

OPTICAL BRANCHING

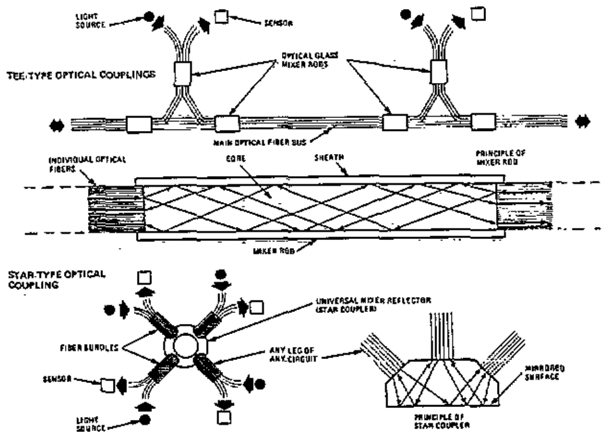

Figure 5. Fiber Optics Cable Configurations

ABOUT THE AUTHORS

DR. ORIN E. MARVEL is a Project Staff Engineer with Honeywell and Staff Advisor on advanced digital technology. He has worked at Honeywell since 1970, and is presently expanding Honeywell Marine Systems Division's role in the development and analysis of fiber optics, microprocessors, and advanced semiconductor memories. He earned his B.S.E.E. and M.S.E.E. degrees at Georgia Tech and Ph.D. in electrical engineering at the University of Illinois. In addition, he attended the U.S. Army Ordnance School and Guided Missile School in Huntsville, Alabama. He is a member of numerous professional societies including: IEEE and USAF Scientific Advisory Board on Guidance and Control.

MR. W. H. LUNCEFORD, JR. has been assigned to the Surface ASW Trainers, including Device 14E24A, since coming to Naval Training Equipment Center in 1974. He has a degree in electronic technology from Pinellas Vocational Technical Institute, Clearwater and a B.S.E.E. degree from Florida Technological University, Orlando, Florida. He is a Masters candidate in computer science there.