COMMUNICATIONS APPLICATIONS OF FIBER OPTICS

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Low loss optical fibers are the basis of a new communications technology which is just emerging. Field trials of data links incorporating optical fibers are underway. For maximum efficiency and economy a communication system must be specifically designed to take advantage of the properties of optical fibers.

Data transmission over optical fibers is a rapidly developing new technology. Over the past few years a wide variety of components has been developed for application to fiber optics communication systems. These components were first assembled into laboratory demonstration communication systems links. Now field demonstration links are being deployed to evaluate the potential of this new technology under actual operating conditions.

In the United States ATT and GTE have both announced field trials for PCM telephone communication links. The Navy is placing an optical fiber link aboard an A-7 aircraft in the aloft program. There is an optical fiber telephone communications link aboard the USS Little Rock, and a CCTV system aboard the USS Kitty Hawk.

These demonstration systems by no means define the limits of interest in this technology. The Army and the Air Force both have programs to develop fiber optics communications for their particular needs. Several companies have made studies of the feasibility of applying fiber optics to CATV systems.

Optical fibers first attracted attention as a transmission medium because of their low loss and wide bandwidth. It was realized that their small size, low weight, and dielectric properties were also advantages. They are immune to RFI/EMI and EMP. Further advantages are the absence of grounding, cross talk, and short circuit problems. Probably their greatest disadvantage is that they represent a new technology. New components and systems must be developed in order to exploit the advantages. The personnel that will deploy and maintain the new systems must receive new training. An additional disadvantage at present is their high cost. However, estimates have been made that project drastic price reductions in large volume production.

Low loss and wide bandwidth do not directly translate into system parameters. For instance, electronics allow trade-offs between bandwidth, loss, and repeater spacing. A comparison between this new technology and present technology can only be made if systems designed for the same application are compared. If optical fibers are used in PCM telephone links, greater repeater spacing can be achieved and more channels transmitted through the same underground ducts than with coaxial cable or twisted pair.

If optical fiber data links are used aboard aircraft, size and weight reductions are achieved. The weight penalty costs for high performance aircraft is in excess of $1000 per pound over the life cycle of the aircraft. In part, the gain is achieved by reduction of the size and weight of the cable, and in part by the elimination of protective devices installed on coaxial and twisted pair transmission lines to reduce EMP and EMC problems.

Optical fiber technology will find widespread application outside of the telephone industry and DoD. The advantages that accrue to these users by employing optical fibers are sufficient to justify the large investment necessary to bring this new technology to fruition. Once the initial development is completed, component pricing is expected to follow the traditional trends of the semiconductor industry. It is at that time that the technology will be open to exploitation by such cost conscious industries as CATV.

When optical fibers are first considered for an application such as CATV, the initial approach is usually a simple retrofit. Often such projects are far from a complete success. The architecture of present systems is strongly influenced by the properties of coaxial cable and twisted pair transmission at VHF. These properties are significantly different from optical fiber transmission of optical energy.

One of the most significant differences is that $h\nu$ is six orders of magnitude larger in the optical region than in the VHF region of the spectrum. This does not indicate that the dynamic range is 60 dB lower for optical systems compared with VHF systems, the minimum detectable signal of a VHF system is usually determined by cross talk, EMC, and noise sources such as cars and lighting.

System dynamic range is also determined by the available source power. LED and laser optical sources have power outputs of the order of a few milliwatts. In contrast, the output power of VHF CATV repeaters can be a few tens of milliwatts. The dynamic range for an optical system with a bandwidth of 3.5 MHz, an avalanche photodiode detector, and a laser diode source is 80 dB.

The bandwidth of optical fibers is a strong function of their construction. Single mode optical fibers have bandwidths on the order of ten GHz/km, graded index fibers one GHz/km, and step index fibers 30 MHz/km. Since the dynamic range of optical systems is restricted, they are seldom designed to have significant signal energy above the upper 3 dB frequency of the transmission channel. This precaution reduces equalization to a minimum. The losses of all three fiber types are essentially identical. Ten dB/km fibers are readily available today and two dB/km fibers have been demonstrated in the laboratory. There is excess loss when a fiber is incorporated into a cable, but this loss is held below one dB/km in good quality cables.

The two most promising sources for the transmitter are the light emitting diode and the laser diode. Both can be tuned to the windows in the fibers by materials selection. In each case the source selected has an influence on system architecture through its particular physical properties. The candidates for the receiver optical detector are the PIN and the avalanche photodiode. The latter contributes internal gain and hence greater receiver sensitivity at the expense of greater receiver circuit complexity.

A video signal can be transmitted over the optical fiber by AM, FM, pulse code and pulse position modulation techniques. Amplitude modulation can be implemented with the least complex receiver and transmitter electronics. However, the large dynamic range necessary for faithful picture reproduction leaves little margin for coupling and transmission losses. If only one AM video signal is transmitted over the fiber, no advantage can be taken of the large bandwidth of the fiber compared with the relatively narrow bandwidth of a video signal.

In contrast to AM, pulse code modulation requires a small signal margin at the receiver at the expense of a bandwidth in the neighborhood of 100 MHz for a single video channel. With the proper selection of components a high quality video signal could be transmitted over six miles of fiber without a repeater. Pulse code modulation requires even greater bandwidth, but greatly reduces the complexity of the electronics. Frequency modulation allows a trade-off between bandwidth and dynamic range with relatively simple electronics.

If greatest economy is to be achieved, the application of fiber optics to trunk and end distribution will require the use of different modulation formats for each application. For the trunk transmission the number of repeaters is minimized if pulse code modulation is used. The short paths in the distribution net can be adequately implemented using AM or FM with a minimum of circuit complexity at the receivers.

For most economical use of the fibers, the architecture of the distribution net will also be different from present systems. While taps on an optical system are possible in most systems, optical scramblers used in association with parallel distribution are more economical. Color multiplexing can be used to increase capacity over a single fiber.