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FIBER-OPTIC SWITCH FOR CATV SYSTEMS

ABSTRACT

We describe a single-mode fiber-optic switch for use in an AM CATV transmission system. This paper will discuss several applications, including the incorporation of a standby laser to fulfill the need for redundancy. This switch allows for system testing, such as OTDR traces and optical power testing, without breaking splices or losing fiber transmission. In all of its applications it introduces no measurable system degradation. A detailed description with diagrams as well as performance characteristics are given.

The Corning fiber-optic switch is well suited for several CATV applications. Some examples are transmitter/receiver back-up, system testing, and networking. Three performance parameters become critical when dealing with optical switching: far-end crosstalk, insertion loss, and backreflection. An understanding of these parameters and the switch function is necessary before the switch's performance can be fully appreciated.

A switch is a four port two state device with the capability to connect either input port to either output port.(FIG.1) In the bar state, port 1 feeds port 2 and port 4 feeds port 3. In the cross state, port 1 feeds port 3 and port 4 feeds port 2. It is the transition between bar and cross states that constitutes switching in this device.

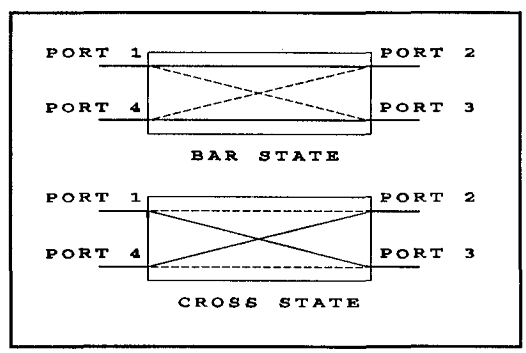

Figure 1 Optical Switch States

Far-end crosstalk is a measure of the amount of light reaching the undesired output port. Specifically, if the switch is in the bar state, and light is input into port 1, then the far-end crosstalk is given by 10 log(P3/P2), where Pi is the optical power at port i. For the cross state the ratio is simply inverted. This "bleed over" of power can cause signal interference. In many AM applications crosstalk values of less than -20dB are required to sufficiently suppress this interference.

Insertion loss is a measure of the amount of power lost between the input and the desired output port of the device. With the switch in the bar state and light launched into port 1, the insertion loss is given by 10 log(P2/P1). High insertion losses can reduce the signal to noise ratio in an AM optical transmission system. Insertion losses of 0.5 dB or less are acceptable for these systems.

Back reflection or return loss is the ratio of optical power reflected back out of the input port to the power input. Directivity or near-end crosstalk similarly characterizes the power leaving the other input port. For example, directivity is given by 10 log(P4/P1), if power is launched into port 1. These reflected signals in an AM fiber-optic system can contribute to noise in the transmitter. It is best to keep both back reflection and directivity below -40 dB to preserve signal quality.

The Corning fiber-optic switch performs well in all three of these critical areas. It typically exhibits far-end crosstalk of -20dB, insertion loss of 0.3dB, and backreflection of less than -55db. This allows the introduction of the switch into AM fiber optic CATV systems with minimal degradation of signal quality.

Switching is achieved in the Corning optical switch through the perturbation of a 2x2 fiber-optic coupler(i.e. a coupler with two input fibers and two output fibers). Fiber optic couplers are an increasingly common element in fiber-optic networks. Typically they are used to split the optical signal among multiple paths. Many of these couplers rely on the coupling achieved between two fibers brought into close proximity, usually by tapering and sometimes by etching. The coupling between the two proximate fibers can be stopped by bending the coupling region so that the signal continues to propagate solely in the input fiber.

One of the technologies that can be used for coupler fabrication utilizes a three-index tapered glass structure, made up of two fibers inserted into a tube (of a third refractive index) which is then necked down to the particular radius required to achieve a particular degree of coupling. For the switch application, a coupler is made such that 100 percent of the light is coupled from the input fiber to the second fiber. With bending, the percent of light coupled to the second fiber can be varied from 100 percent to 0 percent. The bend radius required to reach 0 percent coupling is on the order of 20 centimeters. This bend can be obtained with roughly a 1mm displacement of one end of the approximately 50mm long coupler. Glass, being an elastic material, does not fatigue due to repeated bending, which has been confirmed by switching many devices each over a million cycles without breakage. The three-index coupler technology provides a stable, ruggedized structure in which the coupling can be easily and reproducibly controlled with bending. Therefore, switching can be achieved in a device in which the light never leaves a waveguiding structure (in contrast to moving fiber and moving prism optical switches), thereby yielding a robust switch with low optical losses, low back reflection and high reliability.

A useful application for the switch is in system back-up or redundancy. A "hot" stand-by back-up transmitter can be switched on line if a failure occurs in the primary system.(FIG.2) The switch can be activated manually or by remote logic from a status monitoring system. A system such as this was displayed by Scientific Atlanta at the 1989 Western Cable Show with great success. In this system, the isolation of the switch prevented the back-up and primary transmitters from interfering with each other, eventhough both devices were fully active. This aplication can be expanded to accomodate multi-laser systems.(FIG.3) Receivers also can be switched on line as back-ups in the event of a failure.(FIG. 4) If the ideas in figures 2 and 4 are combined by stacking switches in series, either transmitter can access either receiver. This also allows the use of a back-up fiber which could be accessed if a break were to occur in the primary path.(FIG. 5)

Another application allows system testing without ever losing fiber transmission.

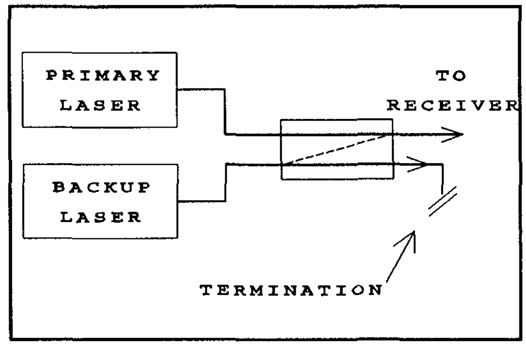

Figure 2 Transmitter Backup

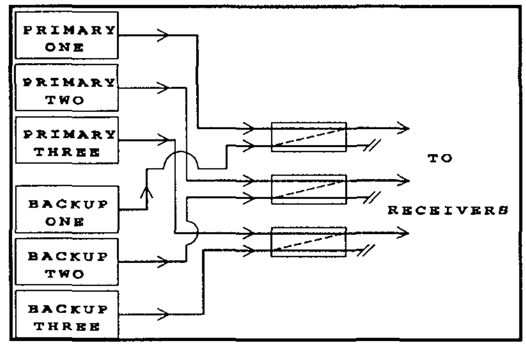

Figure 3 Multi-Transmitter Backup

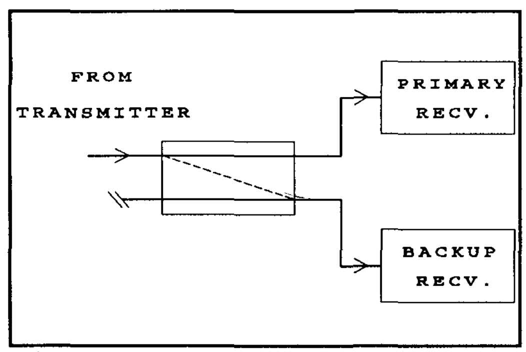

Figure 4 Receiver Backup

(FIG. 6 & 7) Suppose it is desired that an OTDR trace be generated as well as having the laser power level determined. In order to do this, switches must be stacked so that a back-up system can be accessed. The first switch(S1) sends an output to the primary receiver and a power meter. The second switch(S2) sends an output to

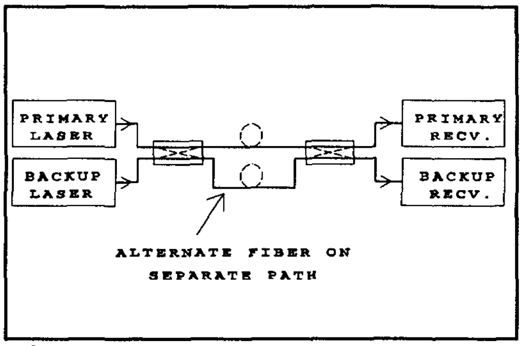

Figure 5 Backup Path

S1 and the back-up receiver.(FIG. 6) When both switches are activated (FIG. 7), the back-up laser will feed the back-up receiver to give fiber transmission. An OTDR trace can be run through S2 to S1 and then to the primary receiver. The primary laser is switched to a power meter to get a power measurement. This application will prevent any downtime during system testing.

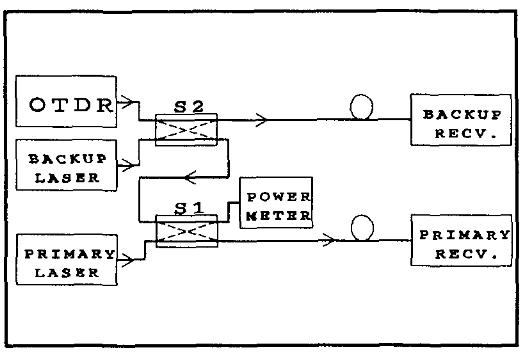

Figure 6 Before System Test

Another application for the switch is networking. By cascading several switches, the number of access points increases exponentially. This could be useful for status monitoring datalinks or a reverse video link for measuring signal quality directly. With various combinations of switch states, every hub could be accessed.

Switch isolation is sufficient to prevent the effects of noise funneling and interference caused by having many sources feeding one receiver. (FIG. 8)

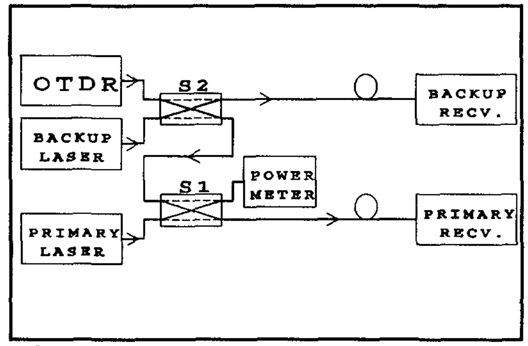

Figure 7 During System Test

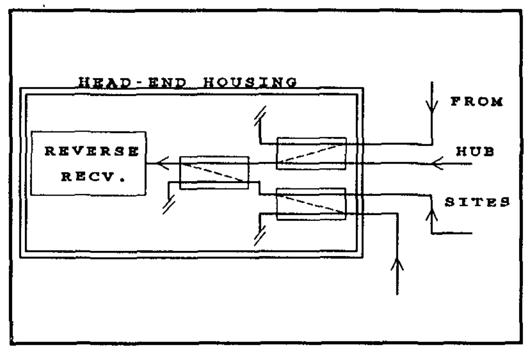

Figure 8 Reverse Receiver

The switch's versatlility lends itself to many applications in fiber-optic AM CATV systems. The performance parameters allow it to be introduced into these systems with minimal degradation of signal quality. With the growing interest in system redundancy and status monitoring, the Corning fiber-optic switch promises to be a significant development in AM CATV.