

# IMPACT OF DISPERSION ON ANALOG VIDEO TRANSMISSION

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## **ABSTRACT**

As the development of 1550 nm AM technology progresses, the impact dispersion will have on analog transmission has become an important issue. This paper discusses the effects of dispersion on AM video signals and possible solutions that will allow for the utilization of 1550 nm AM systems on standard single-mode fiber.

## **INTRODUCTION**

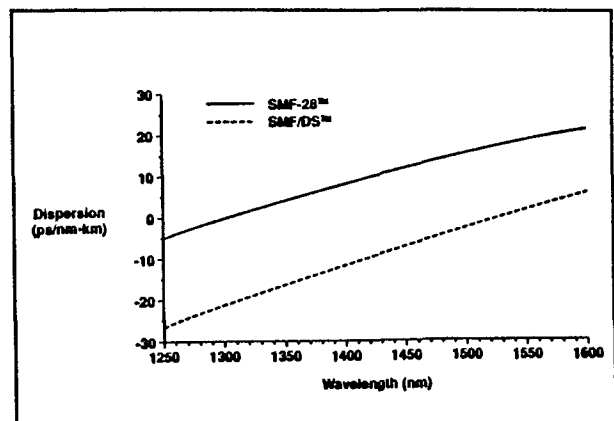
As the development of 1550 nm AM technology continues, it is imperative that we evaluate and understand the effects that dispersion, which is greater at 1550 nm than at 1310 nm on standard single-mode fiber, will have on signal quality. Recent testing has discovered that high dispersion will cause a significant increase in the composite second order (CSO) distortions. CSO degradation was found to be one of the limiting factors on 1310 nm AM systems and with increased CSO degradation occurring at 1550 nm, there appears to be some uncertainty within the cable TV industry on the future of current 1310 nm fiber systems and their potential for 1550 nm upgrades.

## **CAUSES OF DISTORTIONS**

There are two characteristics of today's lasers and fiber that contribute to CSO degradation of analog video signals: laser chirp and fiber dispersion.

The laser characteristic that contributes to the delay in analog transmission is called laser chirp. Laser chirp is caused by

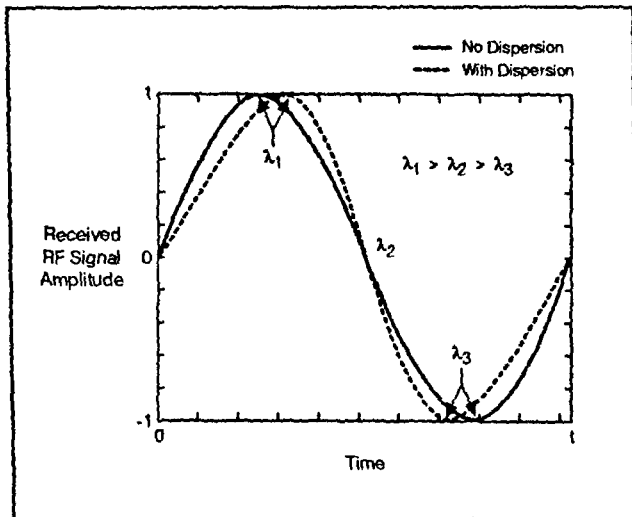
changes in the refractive index in the cavity of the laser due to changes in the current applied to the device. As modulation is applied to a laser, the current through the laser increases and decreases as a function of the applied modulation. When the current is at its peak, the wavelength of the laser is increased. When the current is at its minimum, the wavelength of the laser decreases.



**Figure 1** Typical dispersion for Corning's SMF-28™ and SMF/DS™ single-mode optical fiber.

The fiber characteristic that contributes to the delay is dispersion. Standard single-mode fibers are designed to have zero dispersion near 1310 nm. However, dispersion increases in a single-mode fiber with wavelength due to changes in the fiber material index of refraction. By examining Figure 1, it can be seen that as the wavelength of the laser increases,

there is an increase in the delay caused by the fiber.



**Figure 2** Delay distortion produced when a sine wave is transmitted on high dispersion fiber.

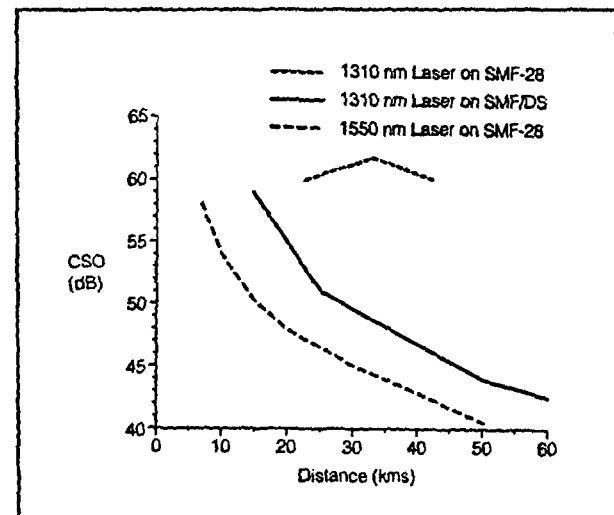
Together these two characteristics cause an amplitude dependent signal delay. This delay causes a transmitted sine wave to distort its shape, thus generating CSO distortions that significantly degrade signal quality. If you were to analyze a single RF carrier, the effects of this delay would cause the positive portion of the carrier to travel faster than the negative portion of the carrier, thus distorting the carrier's shape as it propagates through the fiber cable (see Figure 2 from [1]).

#### **ANALOG DISPERSION EFFECTS**

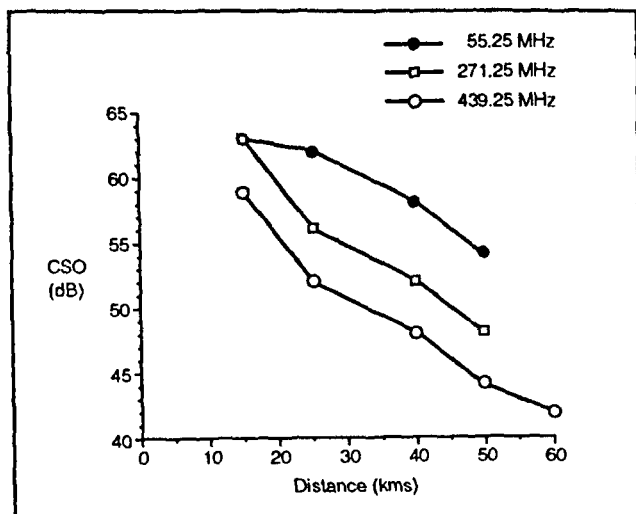
Several tests have been conducted to determine what the effects of high dispersion would be on an analog signal. In one test, a 1310 nm laser was operated on dispersion shifted single-mode fiber to create a high dispersion optical path. This test was conducted using 60 channel loading. Tests were also conducted by Synchronous

Communications Inc. using a 1550 nm laser on standard single-mode fiber. This test was conducted using 35 channel loading.

The CSO of the system was affected by the high dispersion path as a function of the individual lasers. Figure 3 graphically depicts the amount of CSO degradation for a 1310 nm AM system on standard single-mode fiber and on dispersion shifted single-mode fiber, and for a 1550 nm system on standard single-mode fiber. Both the 1310 nm and the 1550 nm systems show a substantial decrease in the CSO performance when operated on fiber that is not optimized for that wavelength. The 1310 nm system operation was virtually unaffected when operated on standard single-mode fiber. There was also a frequency dependence observed. As the carrier frequency increased, the effects of high dispersion were more pronounced (Figure 4).



**Figure 3** Effect of dispersion on CSO.



**Figure 4** Effect of dispersion at multiple frequencies.

### SOLUTIONS TO THE PROBLEM

The results clearly show that the performance of 1550 nm analog systems on standard fiber will be degraded, but there are several things that can be done to minimize the problem. These include delay compensation, operations in octave bandwidths, improved laser technology, the use of digital modulation, and the use of dispersion shifted fiber.

Synchronous Communications Inc. made a presentation at the SCTE Fiber Optics 1991 conference in Orlando [2] that stated the delay distortions, that are experienced at 1550 nm on standard fiber, could be compensated for with an electrical distortion compensation circuit. The compensation circuit produces the opposite effect of the fiber and laser delay characteristic. The circuit, which has been patented by Synchronous, produces voltage variable delay by using the applied modulation to vary the voltage across a varactor diode. The varactor, which changes its capacitance as a

function of voltage, is used in conjunction with an inductor to form the voltage control variable delay circuit. Tests with the compensator circuit installed on a transmitter and optimize for 12 km of fiber, achieved CSO levels of 60 to 64 dB over 5 to 17 km of standard single-mode fiber. Since the delay distortions are distance dependent, the circuit may need to be installed at receivers since transmitters will be shared among multiple receivers over various distances.

Another method for dealing with the CSO problems will be to place all of the signals into a single octave of bandwidth. When all of the channels are placed in an octave of bandwidth, no combinations of channels will produce second order products that will fall within this octave. This may be the most practical solution for dealing with the expanded channel capacity issue that concerns most operators who have already installed fiber. Since our present 1310 nm AM systems are capable of delivering 50 to 450 MHz on a single fiber, when channel expansion is desired, the additional channels up to 900 MHz can be added to a 1550 nm AM system without any second order products. With the addition of wave division multiplexers at transmit and receive sites, the fiber system can be easily upgraded. As 1310 nm lasers improve, this technique should allow expansion to 1 GHz bandwidth.

Alternate modulation methods may also be used on the signals that are transmitted on 1550 nm systems. ATC believes that most of the bandwidth past 550 MHz will be used for pay per view (PPV), near video on demand (NVOD), and other services that may be non-entertainment. If the services are PPV or NVOD, then VSB-AM may not be an appropriate modulation

technique since it is difficult to secure VSB-AM signals without causing visual impairments. Digital modulation for these services would be a more likely choice and would solve two problems at one time. It would avoid the dispersion problems associated with AM transmission and at the same time it would make transmission of these pay services more secure. However, digital modulation is not without its problems. The useable bandwidth (bit rate) of a digital system will be determined by the same dispersion that causes CSO problems in AM transmission. Without the development of compression, the number of digital channels that will be available on a single laser at 1550 nm will be limited.

Another method of dealing with the problems of dispersion at 1550 nm on standard single-mode is to install dispersion shifted fiber. There will be applications that require cable operators to deliver signals over longer distances than are possible with today's 1310 nm systems. Using 1550 nm lasers and dispersion shifted fiber, a system radius could be extended 1.5 to 2 times the distance at 1310 nm. When these scenarios arise, dispersion shifted single-mode fiber and 1550 nm will probably be the lowest cost alternative when compared to FM and digital super trunking.

Many of the new laser structures that are in the laboratory today will also minimize dispersion effects. Most of these new structures will result in narrower line widths and a significant reduction in laser chirp. Since dispersion is proportional to chirp, the dispersion effects will be reduced proportionally to the reduction in these items. External modulation of lasers could also substantially reduce the delay distortions. External modulation eliminates laser chirp and the lasers that are used have

very narrow line widths which makes them a viable alternative.

### SUMMARY

There are problems associated with the use of 1550 nm on standard fiber, but there are also many methods for dealing with the problems. The solutions that are described above will solve most of the problems caused by dispersion and any one or a combination of them may be used to allow the continued expansion of existing and future fiber systems.

### REFERENCES

- [1] H. Gysel et al., Electrical Pre-Distortion to Compensate the Combined Effect of Laser Chirp and Fiber Dispersion. Electronics Letter, Issue 5, February 28, 1991.
- [2] H. Gysel: CATV AM Optical Transmission Links Using the 1550 nm Window, SCTE Fiber Optics 1991, Orlando, Florida, January 1991, pp 161-166.
- [3] L. Williamson et al., Effects of Chromatic Dispersion on Analog Video Transmission. SCTE Fiber Optics 1991, Orlando, Florida, January 1991, pp 177-183.

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