

# **The Role of A Linearized External Modulator in The Video Distribution Network**

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## **Presentation Summary**

The past two years has seen the introduction of high quality linear fiberoptic transmitter into the CATV trunk plant. These lasers to date have been limited to 1.3  $\mu\text{m}$ . With the rapid maturity of optical fiber amplifiers (EDFA) which operates at 1.5  $\mu\text{m}$  window, linear source operation at 1.5  $\mu\text{m}$  are becoming increasingly important. This presentation will focus primarily on the use of external modulator as a 1.5  $\mu\text{m}$  signal source. The key parameters influencing the signal source selection will be outlined. Linearization techniques of intensity external modulators will be reviewed. Then, results of an electronic predistortion linearization approach are detailed. The attractive features of using this type of signal source in a video multicast system employing EDFA are also described.

Many research groups have conducted studies on different techniques of linearizing the external modulator. Basically there are two different approaches. One is more involved at the system level. With this approach, both optical [1] and electronic domain techniques [2] [3] have been used. The other technique concentrated more on the device aspects. There are many activities utilizing the latter approach [4] to [6], however, they lack experimental results to date. Regardless of the approach taken, there are fundamentally two distinct problems; one is the optical device domain problems, the other is the RF domain. A good design must take into account the interrelation between these two aspects of the problems. Depending on the type of devices on hand, one has to carefully separate the tasks to be worked on. By properly separating the tasks into the optical and electrical domain, a robust linear external modulator (LEM) can be realized.

The best modulator linearization approach depends on the device under consideration. For CATV applications, the main concern is the performance of the linearized modulator under multi carrier modulation. In the case where electronic signal processing is involved, the EM device response must be made as ideal as possible. The residual non-ideality will likely limit the overall performance.

In the situation where the optical circuit level is involved, the type of optical components making up the device should be carefully selected. Additionally, the stability of the optical circuit component must be taken into account so that the linearized device will maintain a given level of performance over the entire operating range.

In this presentation, an experimental electronic predistortion approach are taken. The standard lumped electrode Mach Zehnder (MZ) modulator operated at 1.5  $\mu\text{m}$  is employed. As a result, the well known device non-ideality must be taken into account. This includes the acoustical resonance and the frequency response peaking. The light source used is an Erbium doped glass laser. The spectral content has three distinct longitudinal modes. The center mode is at 1534 nm. The available output power is + 14 dBm.

Linearity measurements of the LEM are conducted using the arrangement shown in the Figure 1. Due to the large frequency response peaking, the experiment is limited to a 20 channel carrier modulation. The frequency range selected is from 330 MHz to 450 MHz. The measurement results show that a CTB improvement of 17 to 21 dB across the band is achieved. The actual operating

conditions will be determined by the system specification requirements. Specifically, the CNR and CTB must be given in order to optimize the system.

Evaluations of the transmitter system performance are conducted under the following test condition. The average optical received power is at 0 dBm and +3 dBm respectively. To obtain these levels, either optical attenuators or actual fiber links are used. The modulation index,  $m$ , used are 4% and 5.7% per channel, respectively. The CNR are measured to be >56 dBc and >58 dBc across the band for the corresponding modulation indices. The CTB are better than 63 dBc and 67 dBc for the two index of modulation measured. The CSO are measured at selected frequencies outside the band of interest. The purpose is to have a complete system evaluation. They are measured to be better than 67 dBc for both case of measurements.

To achieve higher CNR, one clearly must operate the system closer to the shot noise limit. This means that, both higher modulation index and higher detected power are playing the key roles. The external modulator should have sufficiently high optical output power. However, the maximum modulation index strongly depends on the achievable linearization improvement and the number of modulating carriers for a given CTB specification. For given CTB,  $m$ , and  $N$  (number of carriers) specifications, the highest CNR will be achieved at the maximum allowable incident optical power onto the detector. The limit will be determined by the non-linearity degradation incurred by the detector used. On the other hand, in a system where an EDFA is employed, a different system parameter will lightly to limit the system performance. Therefore, a different system design approach must be evaluated.

Next, the system is evaluated using different fiber links. One measurement conducted used the 45 km 1.5  $\mu$ m fiber link. All the CNR, CTB, and CSO did not suffer discernible degradation compared to the measured value given in the previous section. The detection are performed at the same incident optical received power. Another measurement is conducted using a 13 km length of 1.3  $\mu$ m fiber link. After the 1.5  $\mu$ m signal propagating through the link, there is no detectable degradation in the system

dynamic range. These results provide evidence that the transmitter has low source phase noise. This is expected since the Erbium laser has much longer coherent-length compared to a semiconductor laser diode. Another important point is that the system can be used in a conventional 1.3  $\mu$ m fiber video multicast system. Measurement of this transmitter with a high power EDFA will also be conducted. It is expected that this signal source will be ideally matched to this type of multicast system.

In summary, LEM signal sources is an important alternative source for the EDFA AM-FDM video distribution system. A solid state laser and an external modulator can be teamed to produce a high performance optical AM-FDM video link. One important advantage of the solid state laser is that it has very low optical phase noise. Another key advantage is that a standard 1.3  $\mu$ m fiber can be used with this 1.5  $\mu$ m signal without suffering significant degradation on the system dynamic range, especially the CSO.

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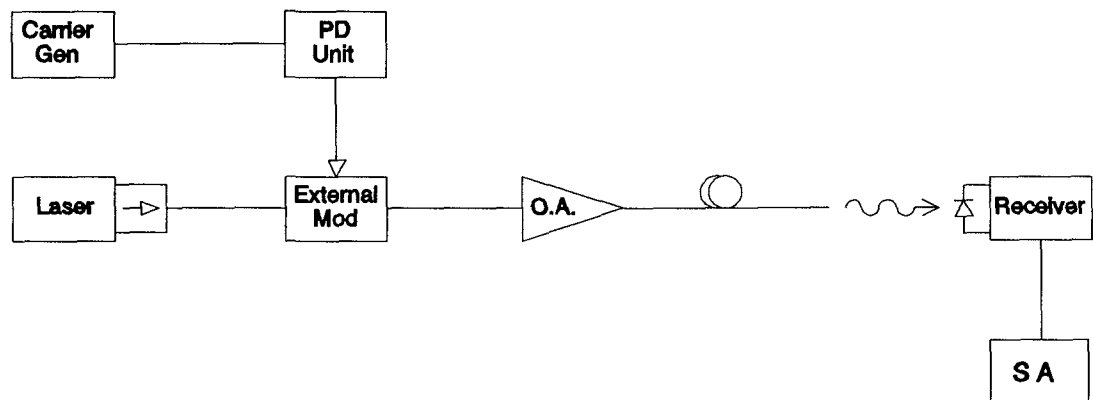


Figure 1. The experimental set-up for measuring both the linearity improvement of the linearized external modulator and the transmitter system performances.