CATV Distribution in A Fiber-in-the-Loop System Utilizing External Modulation

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Abstract

We report results of a video distribution system designed to be deployed in an integrated telephony and television distribution system. This system has been developed to be cost competitive with conventional solutions. The architecture is based on a combined Passive Optical Network - Fiber In The Loop system (FITL): a telephony PON system (Interactive Service) and a television PON system (Distributive Service). The two services are designed to be co-deployed. The video overlay described here can provide up to 50 channels of PAL video. The combination of analog TV distribution and interactive services could be accomplished within a single pedestal.

INTRODUCTION

The cost effective provision of both distributive (am-vsb CATV) and telephony services to the building or pedestal using an integrated fiber optic network is an attractive development for both CATV and telephone companies. This paper describes such a system, developed for large scale deployment in Germany.

In the video distribution system, a high-powered fiber optic transmitter serves many remote optical network units (ONUs). From a headend or central office site, each externally modulated diode-pumped Neodymium Yttrium Lithium Fluoride (Nd-YLF) transmitter feeds up to 64 ONUs located in pedestals or buildings. A tree and branch coaxial cable network distributes the video signals beyond the ONU.

Telephony services are provided over a normal loop at a distance of up to 1000 feet from the ONU. Customers can be provided with Plain Old Telephone Service (POTS), ISDN basic access (BA) and primary rate (PR), and leased lines. The downstream direction uses time division multiplexing (TDM), and the reverse direction uses time division multiple access (TDMA).

A single fiber cable can be used to carry the video and telephony to the ONU , which provides both services.

SYSTEM OVERVIEW

Link description - number of remote sites

The complete video system provides up to 50 channels of PAL broadcast video to subscribers from a Headend through a passive optical network (PON) to as many as 64 distant units (DU or ONU).

Link description - video

Each transmitter has either two outputs each of 12-14 dBm or 4 outputs each of 11-12 dBm. In a typical system, a minimum received power is - 5.5 dBm, giving a link budget of 17.5 dB for each output of the four output transmitter. This allows each output of a four output transmitter to be split 16 ways, each path having typically 2 km of fiber. In this way one transmitter can serve up to 64 ONUs.

Link description - telephony

Each PON tree can provide up to 384 DS0 (64 kbps) channels, with each ONU serving up to 30 subscriber lines. As described below, the optical transmission scheme uses wavelength division multiplexing to enable bidirectional traffic on a single fiber.

VIDEO DELIVERY

Transmitter

The transmitter utilizes external modulation of a c.w. light source, thus separating the functions of light generation and light modulation. This allows the use of high power, low noise optical sources such as the Nd-YLF laser (1) in combination with a zero-chirp modulator such as the Mach-Zehnder waveguide modulator (2).

The combination of a narrow linewidth source and a chirp-free modulator avoids the problems associated with direct modulation ofdistributed feedback lasers (d.f.b.). These include: interferometric intensity noise from fiber backscatter and reflections (3); cavity induced CSO distortion from reflections (4); dispersion induced CSO (5); and, optical amplifier gain slope induced CSO (6). In addition, considerably higher transmitter output powers are available than from present d.f.b. lasers.

The external modulation provides very low chirp and immunity to interferometric intensity noise. The use of feedforward error correction provides very low CSO and CTB, allowing transmitters to be cascaded if required.

Transmitter Design

Optical feedforward (9, 10, 11) is a straightforward analog of electrical feedforward (8). The design of the transmitter is shown in Figure 1. The main optical source is a Nd-YLF laser (1). This is modulated by a balanced-bridge lithium niobate interferometric modulator (12). An error signal is derived by splitting off a small fraction of this modulated light onto a photodetector and comparing this with a sample of the electrical input signal. This error signal is amplified, delayed and then converted to an optical signal by means of a d.f.b laser. This optical error signal is combined with the main signal in a 50:50 coupler in such a way that the error signal cancels the distortion in the main signal.

Two separate feedforward correction circuits are implemented, one for each output of the modulator.This has two benefits. First, the modulator need not be symmetrical in its distortion, and, second, two separate delay adjustments are available to facilitate operation at multiple receive sites.

YLF laser

The light source is a diode- pumped YLF laser operating at 1313 nm. The pump source is a 2 W diode laser, derated to 1 W operation. This laser has an extrapolated MTBF of over 1 million hours. Fiber-coupled output power exceeds 135 mW.

Modulator

The light is modulated by a lithium niobate modulator. This has a +/- 0.5 dB bandwidth to beyond 606 MHz. The modulator has a typical excess loss of below 3.5 dB, and two equal optical outputs, giving a total insertion loss of 7.5 dB per output. Under 50 channel PAL operation at 5%/channel modulation depth, the modulator CTB is ~ 45 dB. The system is designed to reduce this to below 70 dB.

Predistortion and Optical feedforward using dfb correction sources

Linearization is provided by a combination of electrical predistortion and optical Feedforward. It should be noted that because, feedforward uniquely cancels distortions of every order and indeterminate phase, it can be readily combined in this way with any electrical or optical predistortion techniques.

A feature of feedforward is that the error signal is a small proportionof the total signal. Therefore it can show high optical noise without significantly contributing to the overall carrier:noise. Similarly, the distortion of the error signal represents distortion of the distortion, and is a secondary effect. For these reasons, low grade d.f.b. lasers can be used as the error correction source without the noise and distortion limitations mentioned above for systems using d.f.b.s only.

Performance

Each transmitter provides two outputs of 20 mW each, or four outputs of 16 mW each. Measured with 50 PAL c.w. carriers at 5% /channel + 30 FM channels at 4 dB down, the measured CSO is better than 70 dBc and CTB better than 69 dBc.

The transmitter is monitored and controlled using a microprocessor. An external RS485 interface provides full status and alarm monitoring. In addition a timed 3-level optical shutdown and start up is initiated by an external laser safety shutdown (LSS) input. This is controlled by the microprocessor and monitored by a second microcontroller, to ensure reliable operation.

The optical receiver for the video is co-located in the pedestal with the telephony. A typical receiver for this application has a 8 pA/rt.Hz equivalent input noise. The measured optical distortion is less than -70 dBc (second order) and -75 dBc (third order) for a two tone, 40% /tone, test at 0 dBm input power.

Link budget

The system is designed to operate with a minimum link budget of 18 dB for a minimum CNR of 46 dB (5 MHz), with CSO of 62 dB and CTB of 57 dB. Measured results, reported below, are considerably better than this.

TELEPHONY DELIVERY

Forward link

The optical line terminal (OLT) is located near the local exchange. All subscriber information is fed into the OLT, and distributed through the PON to the ONUs. The OLT accepts input lines in multiples of 2 MBit/s and converts them to an internal interface format for maintenance and control. These are then multiplexed and transmitted to the optoelectronics by the bit transport system (BTS). The data steams for both directions are multiplexed on the same fiber by using different wavelengths - 1550 nm for downstream and 1300 nm for the return.

The BTS additionally provides automatic ranging to monitor the path delay of each optical link. Finally, the BTS automatically monitors and controls the transmitted and received power of each link. The ONUs access the allocated Time Division Multiplexed (TDM) time slots and provide the required services to the customer in multiples of 64 kbit/s. Up to 30 POTS lines can be handled by one ONU, and the network management system allows up to 32 ONUs per BTS.

Return Link

The ONU transmits in the reverse direction (upstream) using Time Division Multiple Access (TDMA). Data collision is prevented using an automatic ranging procedure which compensates for the signal delays of the optical routes.

VIDEO RESULTS

Measured results for 50 PAL c.w. carriers + 30 FM channels are shown in Table 1. The launch power was 12.6 dBm and received power -8.5 dBm, giving a link budget of 21.1 dB. This was achieved using 6.4 km of fiber followed by passive loss. Measured modulation depth was 5.07%/channel. The distortion is not corrected for the noise floor. At -2 dBm received, all distortion values were measured at better than 69 dBc.

CONCLUSION

We have described an integrated video/telephony fiber in the loop system. This system is based on co-located passive optical networks for video and telephony. The video transmission system utilizes high power externally modulated transmitters with feedforward error correction. The telephony system uses TDM/TDMA transmission, with bidirectional transmission over a single fiber. There are a number of good reasons to consider this approach to system design. The coaxial part of the video system beyond the ONU could provide a conductive path for AC power for both video and telephone hardware. Interactive video services could employthe telephony for upstream communications requirements, saving the cost of redundant upstream systems. Deploying both video and telephony lines simultaneously would result in a significant reduction in construction costs over independently deployed systems. Finally, the ability to capitalize on future opportunities like digitally compressed video, multimedia and computerized information services can best be addressed by the combined strengths of a combination video (large downstream bandwidth) and telephone (switched) system.

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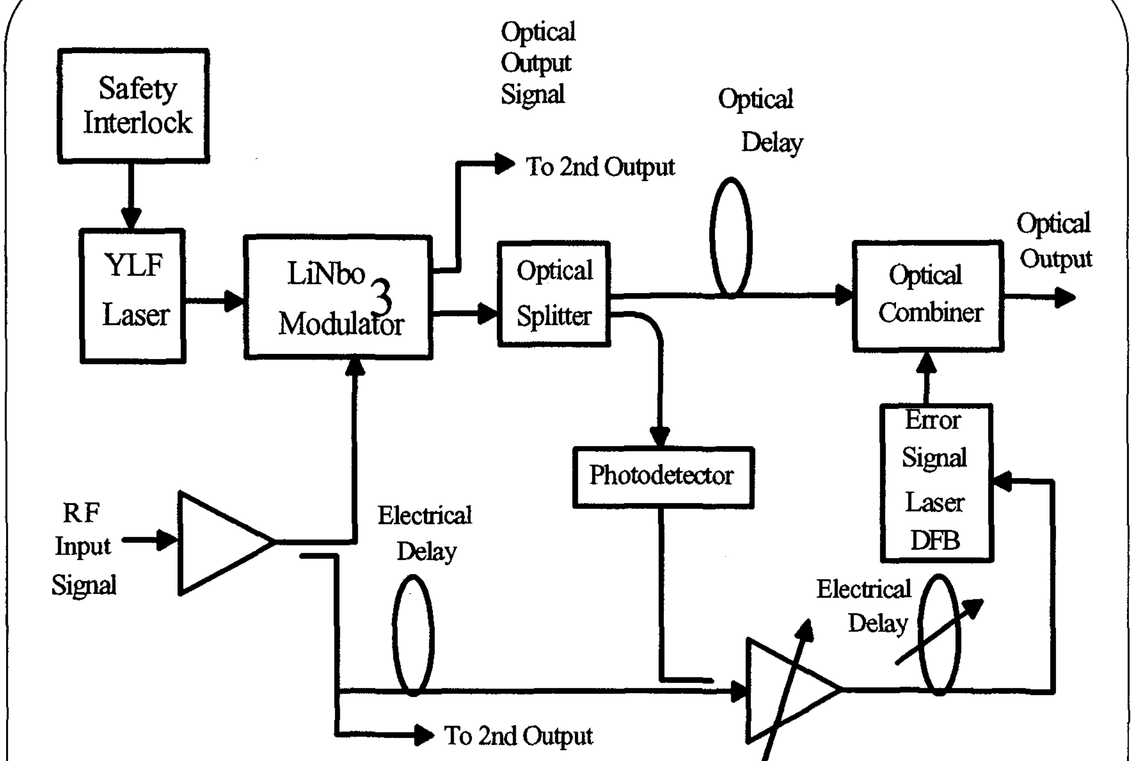
Table 1. Measured Results For 50 PAL c.w. carriers + 30 FM channels

-8.5 dBm received:

	k2 (48.255 MHz)	s37 (431.247 MHz)	k37 (599.246 MHz)
CNR (dB)	46.5	46.4	46.8
CSO (dBc)	70	68.2	68
CTB (dBc)	-	68.4	66.2

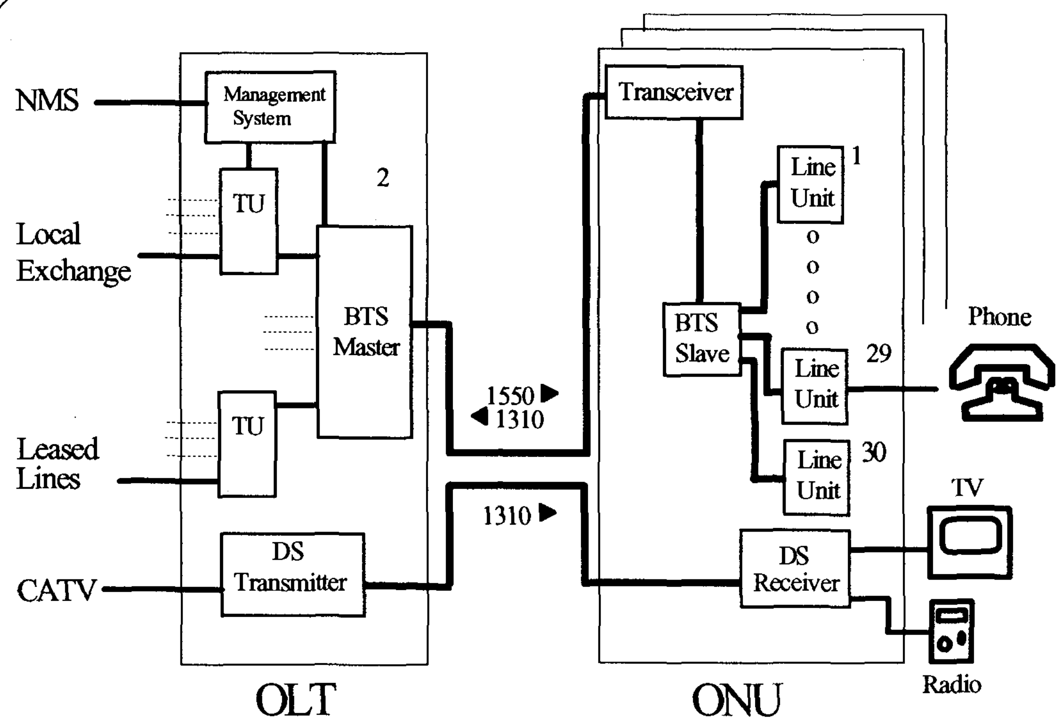
-2 dBm received:

	k2 (48.255 MHz)	s37 (431.247 MHz)	k37 (599.246 MHz)
CNR (dB)	52.1	51.8	51.9
CSO (dBc)	72.7	71.3	71
CTB (dBc)	-	71.5	69.3



External Modulation Laser Transmitter

Figure 1



BTS = Bit Transport System
OLT = Optical Line Terminal
ONU= Optical Network Unit (16 per OLT)
TU = Tributary Unit
POTS = Plain Old Telephone Service (30 per ONU)

Figure 2

Combined Video and Telephone Network