

# Chapter 1

## Introduction

The increasing demand for broadband services raises the need for a high bandwidth link which should extend from the terminals to the customer's premises. In-building networks presently are using a wide range of transmission media like coaxial copper cables, twisted copper pair cables, free-space infrared links, wireless local area network (WLAN) links, etc. Each of these networks is optimized for a particular set of services; this complicates the introduction of new services and the creation of links between services (such as between video and data services). A single broadband multi-services network could provide an efficient solution to host and connect all existing and upcoming services together.

The target for data rate (DR) delivered in home could be up to 1.25 Gbit/s in case of fiber to the home (FTTH) or up to 125 Mbit/s in case of very high bit rate digital subscriber line (VDSL2) technology [1]. The home network must not represent a bottleneck for the expected evolution for services such as the introduction of high definition internet protocol television (IPTV), multi-room and multi-vision configuration and high quality video communication via the TV set. The home network can be used, for example, to share multimedia contents not necessarily delivered in real time by access network, this content can be stored in a device inside the house and used afterwards.

At present, twisted pair and coaxial cables are used as the physical medium to deliver telecom services within the customer's premises. These two transmission mediums suffer from serious shortcomings when they are considered to serve the increasing demand for broad-band services. For instance, twisted pair has a limited bandwidth and it is susceptible to electromagnetic interference (EMI). Coaxial cable offers a large bandwidth, but it poses practical problems due to its thickness and the effort required to make a reliable connection.

Moreover, the coaxial cable is not perfectly immune to EMI and has a certain attenuation. Optical fiber is extensively used for long-distance data transmission and it represents an alternative for transmission at the customer premises as well optical fiber connections offer complete immunity to EMI [2]. Glass optical fibers (GOF), however, are not suitable for use within the customer premises because of the

requirement of precise handling, and thus, the high costs involved. On the other hand, it is important to have very simple and low-cost solutions. Also the enormous capacity of the single-mode GOF is never necessary in this short distance application. The cheap Poly-Methyl-Methacrylate Plastic Optical Fiber (PMMA-POF) is an excellent candidate for implementing such a short distance network.

POF systems provide benefits compared to GOF and copper wire, which include simpler and less expensive components, operation in the visible range (the transmission windows are 530, 570, and 650 nm), greater flexibility and resilience to bending, shock and vibration, ease in handling and connecting (standard step-index POF core diameters are 1 mm compared to 8–100  $\mu\text{m}$  for glass fibers), use of simple and inexpensive test equipment. Finally, POF transceivers require less power than copper transceivers. These advantages make POF very attractive for use within in-building networks [2].

The main disadvantage of the PMMA POF is its high transmission loss (150 dB/km at 650 nm and less than 90 dB/km at 530 and 570 nm) which limits the use of PMMA plastic fibers for transmitting light to less than 100 m. Most cheap commercial POFs have a uniform or step index of refraction that is the same across the core of the fiber, and step-index fibers (SI-POF) have the lowest bandwidth among multimode fibers [2]. This small bandwidth limits the maximum DR which can be transmitted through POF.

To overcome the problem of the POF's high transmission loss very sensitive receivers must be used to increase the transmitted length over PMMA POF. There are two methods to solve the SI-POF limited bandwidth problem: the first method is to use multilevel signaling like Multilevel Pulse Amplitude Modulation (M-PAM) and Quadrature Amplitude Modulation (M-QAM). Also the DR can be increased more with the limited POF bandwidth by using spectral efficient modulation techniques like Discrete Multi-Tone (DMT) [3–6]. In the second method, equalization techniques can also be used to compensate for the SI-POF limited bandwidth. Fixed or adaptive equalizers can be used for pre/post-equalization with different digital or analog equalization methods to increase the POF's bandwidth.

Until now, little effort was done to design an integrated optical receiver with a good performance for multilevel modulation. The optical receiver used with multilevel signaling must deliver a linear response over a large input optical power range. This leads to a more sophisticated design of the automatic gain control (AGC) compared to conventional binary receivers, where a significant part of the large dynamic range is achieved by a simple limiting amplifier.

To receive the multilevel optical signal we need a high linearity optical receiver with multilevel signal. The use of the conventional optical receivers (with limiting amplifier) will not be useful. The use of conventional optical receivers with limiting amplifiers will result in a distorted output signal with unequal voltage levels. This makes the signal decoding very hard or even impossible. In the design of the multilevel signaling optical receiver a linear optical receiver (no limiting amplifiers) will be considered to have equally spaced output signal voltage levels. Also a linear AGC is needed to have a constant output voltage over a wide range of input optical power. This equally spaced output signal voltage levels will ease the selection of

the decision levels for signal decoding from multilevel signal to the original binary signal.

Equalization techniques can also be used to overcome the SI-POF limited bandwidth. Pre-equalization for the light source and post-equalization techniques can be used to equalize for the SI-POF small bandwidth [7–9]. Pre-equalizing of light source (peaking) lowers the light source modulation depth; this reduces the actual power per pulse compared to rectangular pulses without peaking. This is at the expense of the system power budget. A post equalizer introduces additional noise and a higher optical power is needed to achieve the required bit error rate. It follows that the use of pre- or post-equalization methods are of particular interest in systems that have adequate power reserves. Also, for a fixed equalization if the frequency response changes, as a result of different lengths of the POF or a bend in the fiber, the result will be too much or too little compensation and the bit error rate (BER) will increase. The integration of an adaptive POF equalizer with the optical receiver will reduce the system cost and enhance the performance compared to a discrete or fixed POF equalizer [10, 11].

For many applications it is desirable to integrate the photodiode (PD) with a transimpedance amplifier (TIA), POF equalizer, limiting amplifiers, and line driver into the same chip. Placing the TIA adjacent to the PD improves the performance by reducing lead capacitance and sensitivity to interference, thereby giving higher speed and lower noise. A further advantage of the integration of PD with TIA is the reduction in the external circuitry required. Hence overall cost and PCB board size can be reduced.

In this book we show how the fully integrated optical receivers fabricated with a low-cost Si process can help to achieve high transmission performance over standard PMMA SI-POF without any error correction techniques.

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Integrated Optical Receiver Technology

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