Transmission of QAM Signals Over 100m Step-Index PMMA Polymer Optical Fiber with 0.98mm Core Diameter

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Polymer Optical Fiber (POF) is severely bandwidth-limited; to overcome this problem Quadrature Amplitude Modulation (QAM) was chosen for reaching high data rates because of its spectrum efficiency. In this paper we present Digital Video Broadcasting for Cables (DVB-c) transmission using 16-, 64- and 256-QAM modulation over up to 100m Step-Index PMMA POF. An LED as well as a laser source have been investigated. Because a commercially available DVB-c modulator was used for generating the QAM signal, the symbol rate was limited to 7MSps, so bit rates up to 56 Mbps are achieved. The experimental results have been compared with simulation results and match very well. Error Vector Magnitude (EVM) readings as low as 1.65% with 256-QAM were achieved in the experiment, which is promising for further increase in the symbol rate and the fiber length.

Introduction

The great potential of POF is mainly due its large core diameter (typically 750 or 1000 µm) compared to the very small diameter of a silica fiber (8-100 µm), which makes it easy to handle without the need for an accurate alignment [1]. In particular step-index POF with 1 mm core diameter is interesting for cheap short-reach data links, and may become suited for do-it-yourself network installation. A number of problems are associated with using the SI-POF including its severely limited bandwidth. Using Quadrature Amplitude Modulation (QAM) was the idea to overcome the bandwidth limitation for POF because of its spectral efficiency [2].

Digital Video Broadcasting-Cable is the DVB European consortium standard for the broadcast transmission of digital television over cable. The modulation used in DVB-c is QAM with 16, 32, 64, 128 or 256 points in the constellation diagram [3], which makes it a good candidate to be used in the POF transceiver. The wide acceptance for the DVB-c standard in the whole world and especially in Europe produced a large volume market for its products; which made it possible to find commercial DVB-c modems for QAM demodulation at very low prices, and QAM modulators for DVB-c head-ends at moderate prices. It was interesting to investigating the performance of a POF transmission system benefiting from this availability for DVB-c equipments to provide the QAM signal, which also uses an extremely inexpensive system of couplers and photo detectors to couple the light into the POF and to detect it.

System Setup

A commercially available PCI-card for generating DVB-c QAM signal was used in the experiment. The PCI-card QAM modulator is controlled using a software installed in the PC where the PCI-card is plugged in to generate 16- , 32-, 64- , 128- or 256-QAM signals at frequencies ranging from 400 to 862 MHz. This frequency range for the generated signal is far beyond the frequencies that can be used with POF, so a down conversion mixer was always used at the transmitting side as can be seen from Figure 1 which illustrates the system setup.

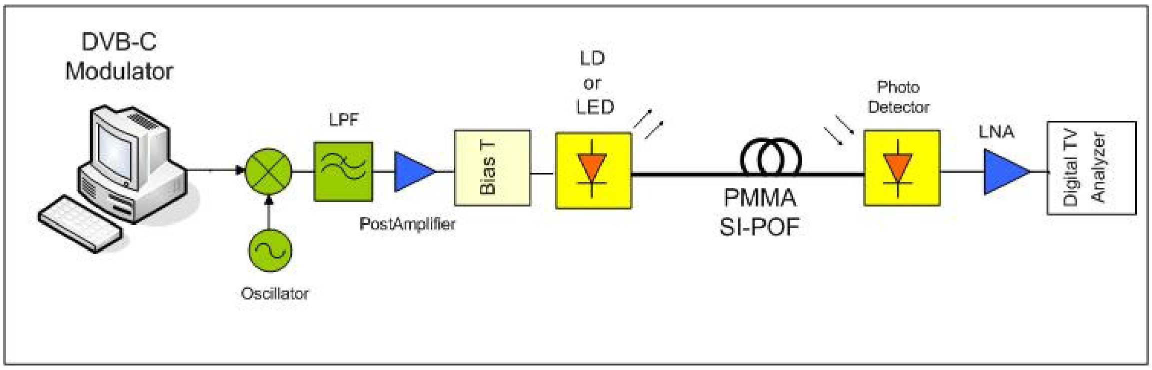


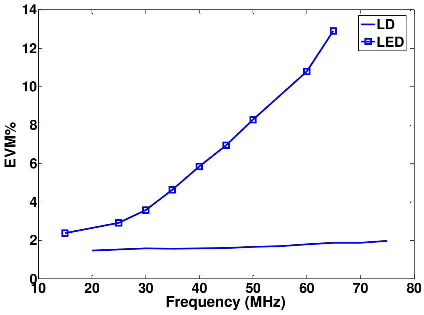
Fig. 1 System Setup for Generating and Transporting DVB-c Signals over POF

The down-converted QAM signal is amplified using a post amplifier with a gain of 20dB to be able to drive the light source, because the output power of the PCI-card QAM modulator is fixed to -25dBm. In the system shown in Figure 1, a laser and an LED were tested. The laser is a red light laser, emitting at a wavelength of 655nm with a linewidth of 2nm, at an output power of 6mW. The LED used is a low cost green light LED, emitting at a wavelength of 510nm with a linewidth of 35nm, at an output power of 5mW.
The transmission medium used in this experiment is a Polymethylmethacrylate (PMMA) Step Index-POF fiber with a diameter of 1 mm, and a length of 100 meters. A very simple plastic connector is used for coupling the light from the light source to the POF. At the end of the POF, a Si Photodiode with an active area of 0.81 mm^2 is used for light detection.

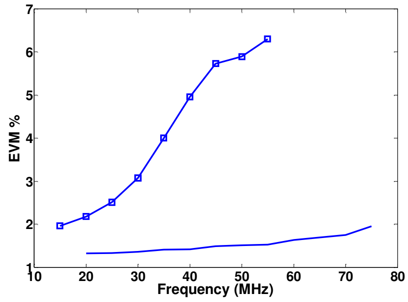
In this experiment, 16-, 64-, and 256-QAM signals were used. The DVB-c standard is limited to 7 MSps transmission rate; which limited the experiment to a maximum bit rate of 56 Mbps when using 256-QAM modulation. A Digital TV Analyzer for demodulating the received QAM signal, and measuring its Error Vector Magnitude (EVM) value.

Experimental Results

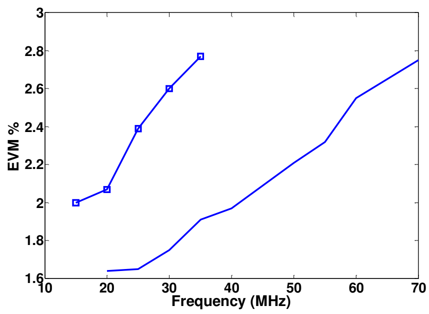
The carrier frequency for the generated DVB-c signal out from the down-converter was swept between 20 and 80MHz. The EVM for the received signal at the photodetector was measured at these frequencies, and an EVM Versus carrier frequency plots were made for the 16- 64- and 256-QAM signals using both the red laser and the green LED; the plots can be seen in figure 2.



a) 16-QAM



b) 64-QAM

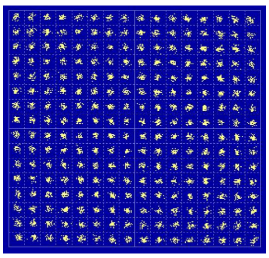


c) 256-QAM

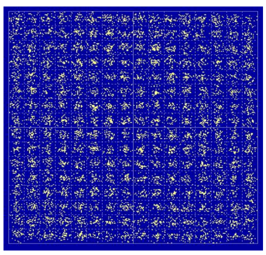
Fig. 2 EVM versus carrier frequency for a DVB-c Signal over 100 meters of 1 mm core SI-POF

No EVM requirements are specified for the DVB-c standard, so the EVM requirements for the IEEE802.11a were used to qualify the signal because of the similarity in symbol rates used in both standards. The EVM requirements in IEEE802.11a for a QAM-16 system (EVM<11.2%) and of a QAM-64 signal (EVM<5.6%), but not specified for 256-QAM so it was considered (EVM<2.5%) which can be considered realistic compared to the requirements for 16- and 64-QAM; from the plots in figure 2 it can be seen that these values can be met using the red laser and the Green LED.

Despite that the green light has a lower attenuation in POF than the red light (attenuation for green is 90dB/km; for red is 150dB/km), but the EVM for the LED was rapidly degraded with increasing the carrier frequency; which indicates that the link bandwidth of the LED-based system is lower than that of the laser-based system; this may be attributed to the large mode volume excited by the LED [2].



a) fc= 20MHz



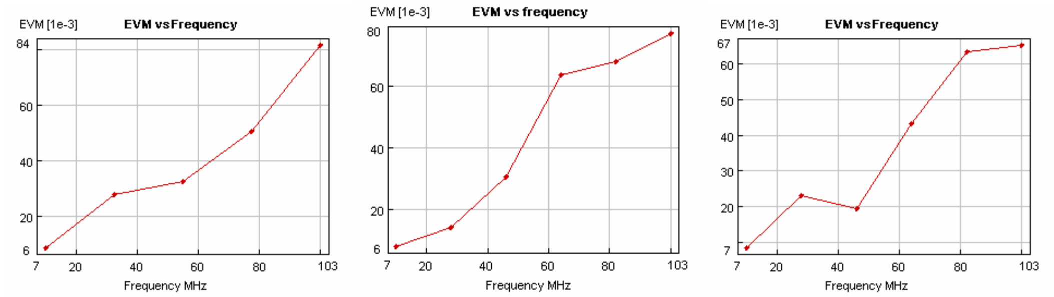
b) fc= 70MHz

Fig. 3 Constellation diagrams for the detected QAM signal after 100 meters of 1 mm core SI-POF

Constellation diagrams for the 256-QAM signal transmitted using laser and probed after the photodetector at carrier frequencies of 20 and 70MHz are shown in figure 3.

Simulation Results

Simulations have been made using VPI Transmission Maker for QAM signals with a symbol rate of 7MSps over 100 meters POF with a laser source to compare their results with the experimental results obtained. The performance of the simulated system is plotted in figure 4; which shows a similar behavior to the system in figure 1, with some differences in the EVM values due to the use of different POF model in the simulation.



a) 16-QAM b) 64-QAM c) 256-QAM

Fig. 4 EVM versus carrier frequency for QAM Signals at a Symbol Rate of 7MSps

Conclusions

A completely commercially available QAM transmission system over 100 meters POF was realized and tested successfully, which can be considered as a start to further increase the length of the fiber and the bit rate to achieve a cheap, easy to install Fiber to the home (FTTH) system. A cheap green light LED was tested and showed a good performance despite of its wide linewidth, and this can be attributed to the relatively low attenuation POF has at green light wavelengths. Simulations for QAM transmission systems showed similar behavior to the tested system.

References

[1] Iracema A. Suassuna de Oliveira and Marlino Bonfim, "Plastic Optical Fibers in Telecommunications: Analysis, Comparison and Applications", in Proceedings of the Conference SBMO/IEEE MTT-S IMOC, 2003, pp. 651-655.

[2] Ton Koonen, Jia Yang, Xinkai Li, Mohammad Alfiad, Jianming Zeng, Henrie van den Boom, "High Capacity Data Transport over Highly Dispersive Plastic Optical Fibre Links using Quadrature Modulation"; in Proceedings of the Conference POF/MOC, 2006.

[3] European Telecommunications Standards Institute (ETSI): Digital Video Broadcasting (DVB); Framing structure, channel coding and modulation for cable systems.