Low Cost High Capacity Data Transmission Over Plastic Optical Fibre Using Wavelength Multiplexed Quadrature Amplitude Modulation

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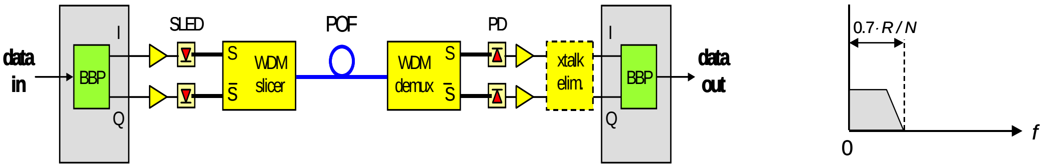
Quadrature Amplitude Modulation (QAM) is considered to increase the channel capacity in bandwidth-limited large-core step-index polymer optical fiber links since it can take advantage of widely used low-cost QAM chips. The baseband in-phase and quadrature-phase signals of the QAM signal can be transmitted in two different wavelength channels with two low cost LEDs, at 460nm and 650nm respectively. In the computer simulation, the occupied bandwidth with this implementation decreased to 1/3, compared to the normal implementation of QAM. Using 16 QAM, 60Mbit/s over 100m 1mm core diameter step-index PMMA optical fiber has been realized. This system showed the feasibility of QAM transmission for low-cost high-speed transmission over large core plastic optical fibre. Using a 650nm red LED which combines the higher bandwidth and enough optical power, the transmission capacity can be increased further.

Introduction

The 1mm core diameter PMMA Step-Index Polymer Optical Fibre (SI-POF) is very attractive for in-building networks due to its large core and its ductility, which ease installation. However, the transmission bandwidth of plastic optical fibre is very limited because of this large core diameter. The -3dB bandwidth for 1mm SI-POF over 100m is just 30.5 MHz [1]. Therefore, multi-level modulation schemes are considered to achieve high-speed transmission. Since QAM technology has been already widely deployed in wireless LAN standards, such as the IEEE 802.11 x families, in digital video broadcast systems on coaxial cable networks (DVB-C), and for fast internet in cable modem systems such as DOCSIS, low cost chip-sets are already available. Thus, on our bandwidth limited 1mm core SI-POF link, QAM is considered to be the best option, by combining two advantages: its high bandwidth efficiency, and low cost chips due to its large market volume.

QAM system implementation

Wavelength-sliced emulated QAM (WS-QAM) [2] for the 1mm SI-POF system is proposed since it is very bandwidth efficient. With this principle, which is depicted in Fig.1 a), I and Q signals are transported both in baseband. Two LEDs are used to generate two optical signals. These two signals are combined using a WDM wavelength slicer and transported via a 1mm core POF. At the receiver side, the optical signal is demultiplexed into the two signals with different wavelength and are detected separately to recover the I and Q baseband signals. This implementation requires the least bandwidth of the POF link, namely only 0.7 R / N as shown in Fig.1 b), where the data rate is R and a QAM-2^N scheme is used.



a) system concept b) spectrum

Fig. 1 Wavelength-sliced emulated QAM

Experimental setup

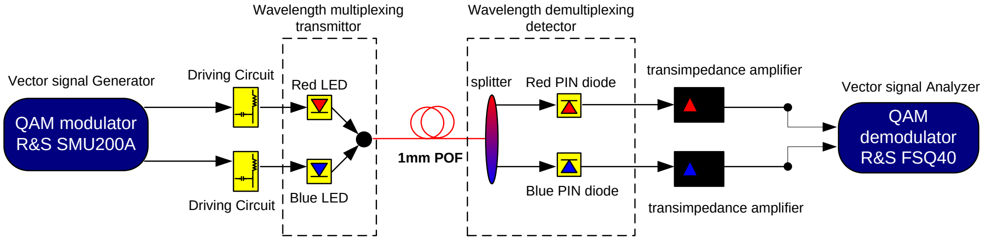
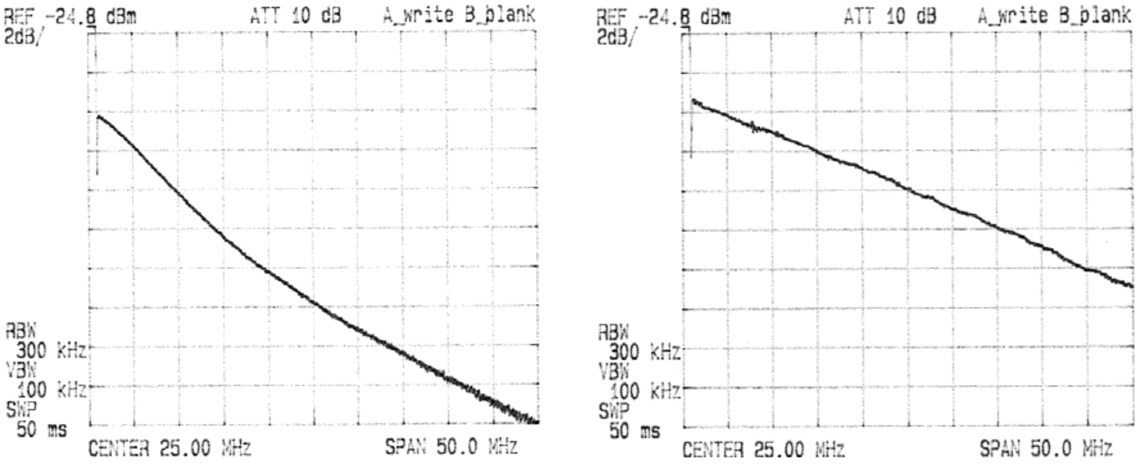


Fig. 2 The setup of the WDM-QAM system

Fig. 2 shows a laboratory setup to demonstrate the feasibility to transport the I and Q signals of a QAM signal with two different wavelengths channels. Two LEDs with different wavelengths and a combiner are used (as no suitable wavelength slicer was available yet). The two 16-QAM baseband I and Q signals directly modulate the two different optical sources: a red LED with 650nm wavelength and a blue LED with 460nm wavelength. The two optical signals are combined with a 1mm SI-POF optical power combiner. At the receiving end, the WDM optical signal is demultiplexed by means of an optical WDM splitter which can guarantee only 10-12dB crosstalk. The separated optical signals are detected by two PIN photodiodes. After the photodetectors, transimpedance amplifiers are deployed, and their outputs are fed to the Vector Signal Analyser (VSA) for assessment of the signal quality.



a) Red channel b) Blue channel

Fig. 3 The back-to-back frequency response of the WS-QAM system

Experimental Results

In this WDM-QAM system, I and Q baseband signals are detected with the QAM demodulator in the VSA. Therefore, it is important that the two WDM channels have the same transmission characteristic. The frequency characteristics of the two channels have been measured and are shown in Fig. 3. As can be seen, the -3dB bandwidth of the red (650nm) channel is only around 8 MHz, while the -3dB bandwidth of the blue (460nm) channel is more than 15 MHz. Thus, the symbol rate is limited by the red LED and the quality of the red LED became the dominant limitation in this system.

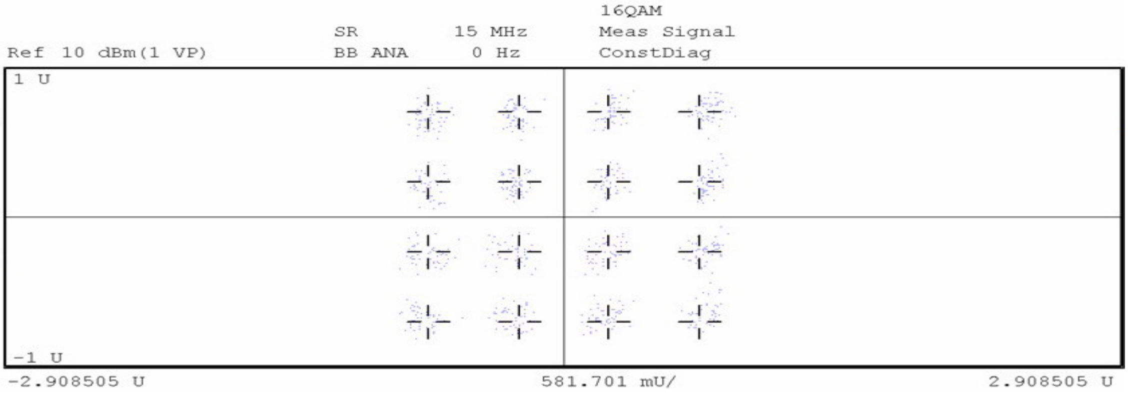


Fig. 4 The measured constellation map of the received 16-QAM signal with a 15MS/s symbol rate

In Fig. 4, the measured constellation map is shown in case of a symbol rate of 15MS/s and 16-QAM modulation format achieving 60Mbit/s over 100m POF with an Error Vector Magnitude, EVM=12.6%.

The Bit error ratio (BER) of the system can be determined by EVM, which is less than 10^{-3} when the EVM=12.6% [3]. The transmission can be nearly error-free if forward error correction is added to the system.

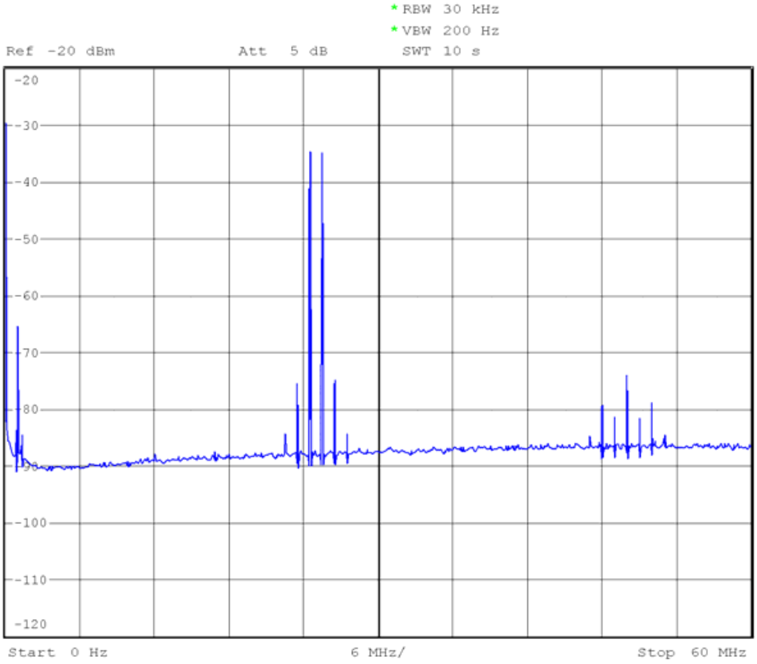


Fig. 5 The spectrum of two-tone measurement (f1=25.5MHz and f2=24.5MHz, with Blue LED)

Non-linearity of the LEDs

The nonlinearity of the LEDs can also limit the capacity in case of multi level transmission. The nonlinearity of an LED can be measured using the well known two tones method. The LED is modulated with two RF signals with equal level and with frequencies f_1=25.5MHz and f_2=24.5MHz. The spectrum of the detected signal can be seen in fig. 5 in case of using a blue LED. The intermodulation (IM) products due to second order distortion are at f_1-f_2=1MHz and f_1+f_2=50MHz. The third order IM is always more significant because the distortion products are at $2f_1$-f_2=26.5MHz and $2f_2$-f_1=23.5MHz which are much closer to the desired frequencies f_1 and f_2. In Fig. 5, the second and third order IM can be both observed. This nonlinearity can lead to degradation of the performance of the transmission, specially in case of using higher order QAM.

Conclusions

The feasibility of transmitting the I and the Q channel of a QAM signal with two different wavelengths achieving 60Mbit/s over 100m, 1mm core SI-POF has been demonstrated. Because of the limited bandwidth of the red LED, the performance of the WDM QAM system is limited. The crosstalk between the red and blue channels did not noticeably degrade the system performance. The WDM-QAM system capacity can be improved by using a red LED that can combine a higher bandwidth and enough optical power. Using higher order QAM, for instance QAM-64, can also increase the capacity further provided that the non-linearity of LEDs can be compensated.

References

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