# Subcarrier Modulated Transmission over Silica and Polymer Multimode Fibres

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*Multimode fibre (MMF) is a suitable medium for constructing a cost-effective converged access network. Compared with single mode fibre the bandwidth of the baseband of MMF is limited. The transmission capacity of MMF can however be increased due to the existence of passbands in the higher frequency region above the -3dB baseband. Multiple subcarrier modulation may explore efficiently the passband characteristics of MMF. In this paper, we demonstrate the transmission of 1.25 Gb/s binary phase shift keying (BPSK) modulated data over 4.4 km 50μm-core- diameter silica MMF and 100 m 50μm-core-diameter graded-index perfluorinated polymer optical fibre (GI POF) by using a single subcarrier channel centered at 3 GHz. Eye diagram and bit error rate measurement results will be presented. Experiments with different subcarrier frequencies indicate the possibility for Subcarrier Multiplexing (SCM) to transport various broadband signals through a common infrastructure with one laser source.*

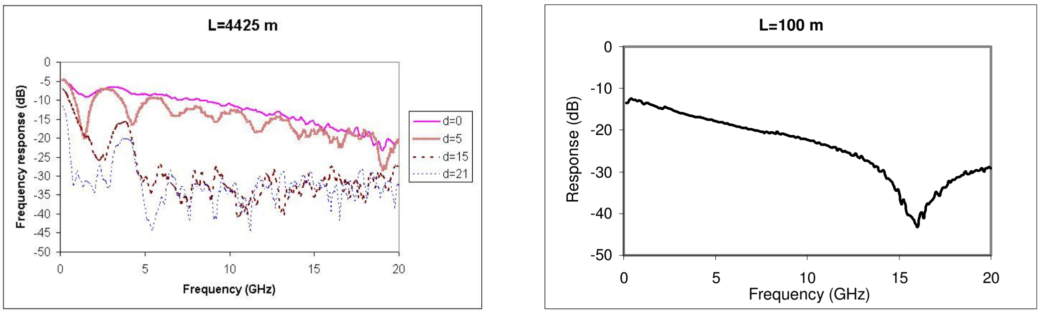
## Introduction

In the final link to the user premises there are various services with widely ranging characteristics and accordingly, dedicated infrastructures to deliver these services, e.g. coaxial cable bus networks for television and radio broadcasting, and twisted copper pair point-to-point links for voice telephony. This situation hampers the introduction of new services and the communication functionalities among these services. Graded index MMF (GIMMF), either silica or polymer, is a preferable alternative to single mode fibre (SMF) for building a common infrastructure to provide different services in a full-service access network.

In a short range MMF-based access network the modal dispersion dominates chromatic dispersion and mode coupling is normally assumed negligible (especially for silica MMF). Under these circumstances, the impulse response of the MMF can be assumed to consist of a number of delta functions which correspond to groups of modes traveling at different speeds. Therefore bandpass lobes at higher frequency region may exist in the transfer function [1]. Fig. 1 shows the frequency response of the silica MMF and POF used for the transmission experiments. By means of subcarrier multiplexing (SCM), these passband regions have the potential to host additional transmission channels for integrating different services into a common MMF link with each service modulated onto a separate carrier frequency.

SCM over MMF demonstration was first reported by Raddatz et al. in 1998 [2] with the transmission of a 200 Mb/s signal on one subcarrier-modulated channel over a 1 km 62.5 μm core silica MMF. Since then this technique has been explored for even higher capacity/speed transmission, together with more spectrally efficient modulation schemes, i.e. quadrature phase-shift keying (QPSK) [3][4]. However, this technique has not been demonstrated on a POF system yet.

We have presented a system concept of a MMF-based point-to-multipoint access network by using SCM techniques [1][5]. The work in this paper is the first step toward realizing such system using a passband for transmission of 1.25 Gb/s over both silica and polymer MMF link.




a) b)

Figure 1: Frequency responses of a)the 4.4 km silica MMF obtained with different offset lauching positions d and b)the 100 m 50 µm core diameter graded index perfluorinated POF measured with central lauching. All were with a 1300 nm DFB laser.

## Setup for the transmission experiment

The experimental setup is shown in Fig. 2. At the transmitter end, a bit pattern generator (BPG) is used to produce a 1.25 Gb/s, nonreturn-to-zero (NRZ), $2^7$-1 pseudo-random binary sequence (PRBS) data stream. Through a double-balanced microwave mixer, this baseband PRBS data is up-converted onto the 3 GHz subcarrier which is generated by an RF signal generator. Either a BPSK or an amplitude shift keying (ASK) signal can be produced at the output of the mixer by setting the BPG properly. The up-converted subcarrier channel signal then directly modulates a 1300 nm Distributed Feedback (DFB) laser. The modulated light is butt-coupled from the single mode laser pigtail into the MMF link. The core diameters of both this 4.4 km silica MMF and 100 m POF are 50 µm. Afterwards the transmitted optical signal is detected by a 50 µm core MMF pigtailed photodiode which has 25 GHz bandwidth. At the receiver end an identical mixer as used for up-conversion at the transmitter was used for demodulation. The RF signal generator is connected to the second mixer through a phase shifter, which is used to correct the phase change after transmission. After the low pass filter (LPF) the down-converted signal was sent to the BER tester and oscilloscope.

## Experimental results

Eye diagrams for both the BPSK and ASK schemes were obtained first. Fig. 3 shows the results of the transmission with the 100 m POF. For these eye diagrams, the optical power into the photodiode was kept the same at -10 dBm. Obviously, the eyes for the BPSK scheme are much more open than those of the ASK, both with the back-to-back and after the transmission of 100 m POF. For the 4.4 km silica MMF, we obtained similar eye diagrams.

This observation is in good agreement with the BER measurement. For the transmission over the 4.4 km silica MMF, as shown in Fig. 4a, we can see that a BER lower than $10^{-9}$ was obtained for each case and there exists a power penalty around 1 dB for both BPSK and ASK at BER of $10^{-9}$. While compared with BPSK, the ASK format resulted in an extra 2.7 dB penalty at the BER of $10^{-9}$.

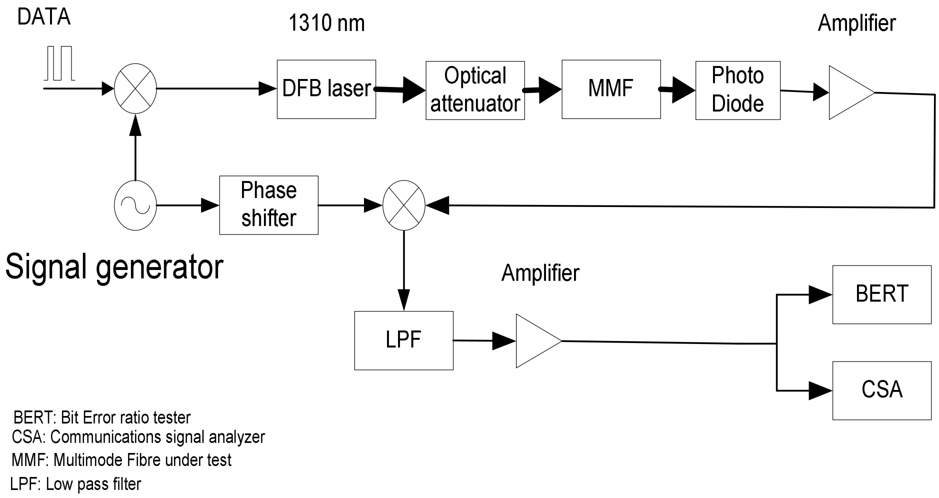



Figure 2: Experimental setup for the one channel 1.25 Gb/s subcarrier modulated transmission over MMF link.

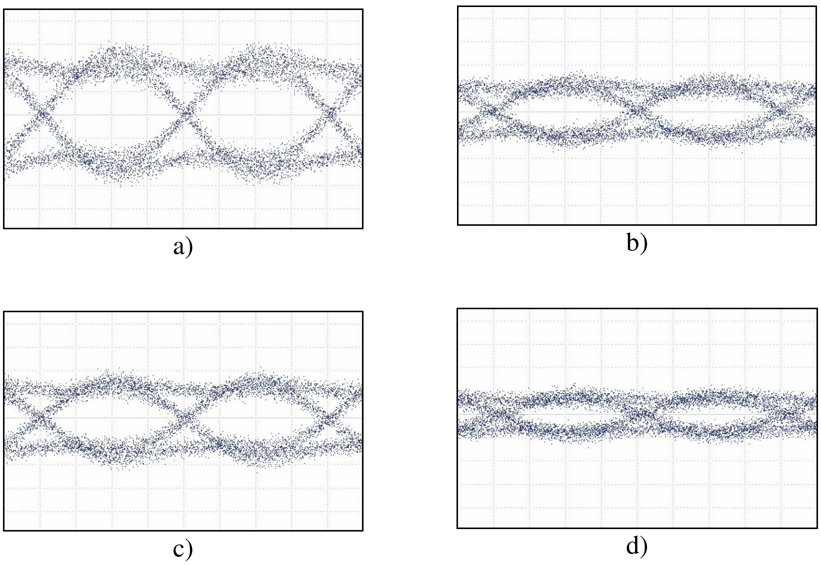
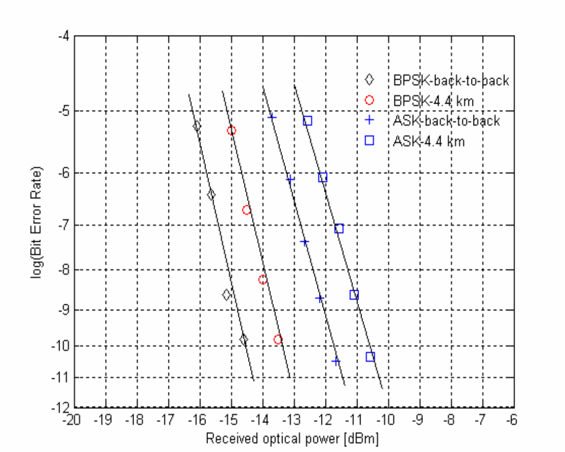



Figure 3: Received eye diagrams of the 1.25 Gb/s subcarrier-modulated channel (200ps/div, 50mV/div). a) back-to-back with BPSK, b) back-to-back with ASK, c) after 100 m 50µm core PF POF with BPSK and d) after 100 m 50µm core PF POF with ASK.

For the 100m POF experiment (results shown in Fig. 4b), the reception is still error-free for the BPSK signal with received power level of -10 dBm, while for the ASK signal, the BER increased to about $10^{-8}$ after transmission. Compared to the back-to-back scenario, at BER of $10^{-9}$ there was a power penalty of around 1.5 dB after transmission for both BPSK and ASK. Compared with BPSK, the ASK scheme resulted in an extra 3.4 dB penalty at the BER of $10^{-9}$.

Furthermore, for both BPSK and ASK schemes error-free transmission was achieved with either the silica MMF link or the POF link.



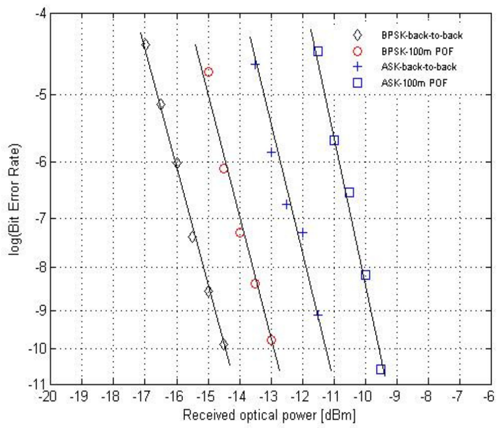




Figure 4. BER comparison between BPSK and ASK subcarrier modulated transmission. a) results of the 4.4 km silica MMF and b) results of the 100 m PF POF.

In addition, experiments with combination of other subcarrier frequencies and bit rates were conducted. The tested subcarrier frequencies were 2.2 GHz, 2.5 GHz and 2.8 GHz for the 4.4 km silica MMF, and were 4.0 GHz, 3.5 GHz and 2.5 GHz for the 100 m POF. The bit rates were 450 Mb/s, 625 Mb/s and 1 Gb/s. Error-free transmission was observed for all these combinations of frequencies and bit rates. This indicates that it is possible to apply SCM techniques onto a silica MMF, or a POF system for delivering different services.

## Conclusions

1.25 Gb/s transmission experiments over 4.4 km silica MMF and 100 m 50µm core diameter GIPOF were conducted with the use of subcarrier modulation techniques. Combinations of different subcarrier frequencies and bit rates were tested for transport in a subcarrier channel. Error-free transmissions were achieved for both BPSK and ASK modulation formats. This experiment demonstrates the feasibility of integrating different services into one silica or polymer MMF system by SCM techniques.

## Acknowledgement

This work is supported by the Dutch Ministry of Economic Affairs under the Innovation Oriented Research Program (IOP GenCom) "Full service access networks using multimode fibre".

## References

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