Wired and wireless multi-service tranmission over 1mm-core GI-POF for in-home networks

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Simultaneous transmission of broadband wired and wireless signals over 50 m 1mm-core GI-POF is demonstrated for the first time. 2.2 Gbit/s DMT and 528 MHz 200Mbit/s UWB wireless signals are delivered with BER $< 10^{-3}$ and EVM $< 15.5\%$, respectively, in accordance with WiMedia standards.

Introduction: Delivery of multiple services through in-home networks does, of necessity, require increased bandwidth. The transmission capacity needed for delivering current and emerging home services can even exceed the access line capacity [1]. Currently, a plethora of delivery methods and cable media are employed for different kinds of services; e.g. coaxial cable for video broadcast, Cat-5 cable for computer data, twisted pair cable for wired telephony, and wireless LAN for Internet. Such multiple network infrastructures lead to a complicated consumer experience and high service and maintenance costs.

To provide a simplified and easily upgradable in-home network, a single common backbone infrastructure is required, as shown in Fig. 1. Whilst singlemode fibre has been considered as a future-proof transmission medium for optical networks, the associated hardware, installation and maintenance costs are prohibitive for mass deployment for brownfield access and in-building networks. Hence, for cost-sensitive in-home networks other solutions should be considered.

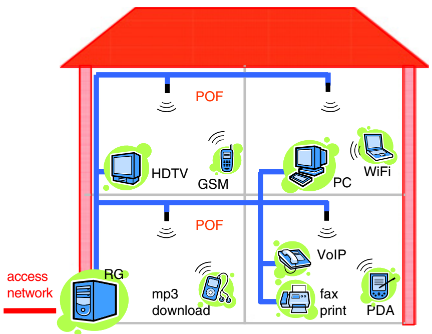

Fig. 1 *In-home POF infrastructure for converged transport of wired and wireless services*

Plastic optical fibre (POF) is potentially a cost-effective solution, especially when sharing the existing ducts with electrical power line cables [2]. Specifically, Ø1 mm core poly-methylmetacrylate (PMMA) POF is becoming increasingly important, owing to the high potential for 'do-it-yourself' installation, easy maintenance and tolerance to bending.

A comprehensive study on large-core POF systems has been carried out to achieve multi-gigabit transmission [3], and to transport broadband wireless signals [4]. This Letter presents, for the first time, simultaneous transmission of broadband baseband and radio frequency (RF) signals using Ø1 mm core PMMA graded-index (GI) POF. We demonstrate the successful transmission of a DMT signal at a data rate of 2.2 Gbit/s and a WiMedia-compliant multi-band (MB) OFDM UWB radio signal at 200 Mbit/s over a 50 m link of PMMA graded-index POF.

Experimental setup and results: The proposed system is based on a simple intensity-modulated direct-detection (IM-DD) optical link. The main bandwidth limitation of the system is attributed to the POF link bandwidth and the optoelectronic components. The photo-receiver in particular has only a 3 dB level bandwidth of 1.4 GHz.

The experimental setup is depicted in Fig. 2. We split the available bandwidth into two separate spectra; for DMT (~0 to 0.8 GHz) and UWB (0.8 to 1.4 GHz) signals. A WiMedia-compliant UWB transmitter generates a real-time MB-OFDM signal centred at 3.96 GHz (TFC6: 3.696–4.224 GHz). Although the standardised full UWB bit rate is 480 Mbit/s, our available UWB transceiver was limited to 200 Mbit/s. To fit within the limited lowpass characteristic of the POF, downconversion of the UWB signal from the RF to an intermediate frequency band (0.836–1.364 GHz) is required. To demonstrate the potential of real implementation, a sampling speed of 1.6 GSamples/s is used at the arbitrary waveform generator (AWG) to generate the DMT signal. A bit and power-loading algorithm is used to optmise the signal constellation format for every subcarrier.

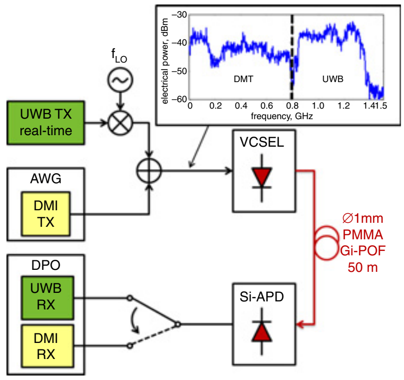

Fig. 2 *Experimental setup for simultaneous transmission of DMT and UWB signals over POF*

Inset: Spectral allocation of DMT and UWB in available bandwidth

The electrically combined signal is used to directly modulate a VCSEL at 667 nm with an eye safe optical emitted power of 0 dBm. The VCSEL is followed by Ø1 mm core 50 m PMMA GI-POF and a photo-receiver based on a Ø230 μm Si-APD, followed by a two-stage electrical amplifier with a gain of 40 dB. The detected signal is fed to a digital phosphor oscilloscope (DPO) in order to capture a time-window of the received signal for off-line performance evaluation. The maximum data rate at a bit error rate (BER) below 10^{-3} for DMT and error vector magnitude (EVM) for UWB is measured.

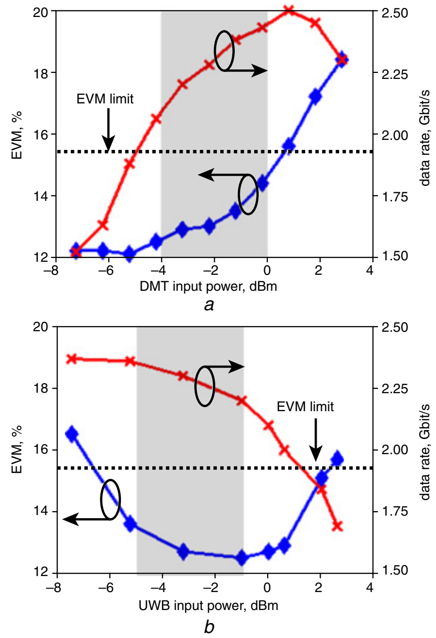

Fig. 3 *DMT and UWB performance against DMT and UWB input power*

a Against DMT input power
b Against UWB input power

Fig. 3*a* shows the performance of the two signals with UWB power fixed to −1 dBm while DMT power varies from −7.2 to +2.8 dBm. For DMT power below 0.8 dBm, the UWB EVM performance complies with the standard EVM limit of 15.5%. The recommended operating region is where the difference between the two curves is the largest, i.e. between −4 and 0 dBm. With DMT power fixed to −3.2 dBm, we repeat the experiment by varying the UWB power, as in Fig. 3*b*. In this case, the recommended region of operation is between the UWB input power of −5 and 0 dBm. In particular, we set the DMT and UWB signal power to −3.2 and −1 dBm, respectively, to achieve 2.2 Gbit/s DMT transmission with the UWB EVM below 13%. In Fig. 4, the received constellation for the subcarriers of the DMT signal with 3 bits allocated is shown. In addition, the QPSK constellation of the demodulated UWB signal is shown. Both constellation plots indicate the excellent quality of the received signals.

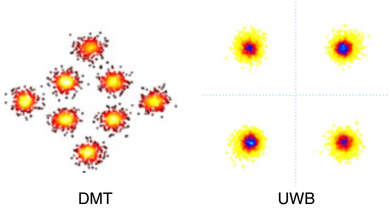

Fig. 4 *Constellation diagrams of received signals after simultaneous transmission over 50 m POF*

Conclusion: We have experimentally demonstrated for the first time a combined transmission of wired and wireless signals over Ø1 mm core 50 m PMMA GI-POF. Two broadband signals are simultaneously transmitted: a 2.2 Gbit/s DMT signal with BER $< 10^{-3}$, and a 528 MHz WiMedia-compliant UWB signal with EVM $<$ 13%. This work validates the use of Ø1 mm POF links as a common infrastructure for in-home networks capable of transmitting wired and wireless in-home services. In addition, implementation costs are minimised by employing simple transceivers, IM-DD optical systems, and advanced modulation formats.

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One or more of the Figures in this Letter are available in colour online.

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