Multi-Channel Broadband Wireless Transmission Over Fibre Using Feed-Forward Linearised Uncooled DFB Laser

T. Ismail, C. P. Liu, J. Mitchell and A. J. Seeds
Department of Electronic and Electrical Engineering, University College London, Torrington Place, London WC1E 7JE, United Kingdom
a.seeds@ee.ucl.ac.uk

Abstract We describe a feed-forward linearisation scheme for the transmission of two 11Msymb/s QPSK modulated wireless channels over 2.2km SMF using an uncooled DFB laser, achieving 5% reduction in the error vector magnitude at –20dBm input.

Introduction
Broadband wireless local area network (WLAN) systems using the IEEE802.11b/g standards are growing rapidly in popularity. To provide large-area network coverage such as at an airport, delivery of the WLAN signals to remotely located access points (APs) using optical fibres is preferred because of the higher transmission loss associated with microwave coaxial cables. An access point can simultaneously receive high- and low- power signals, depending on how far the users are from the AP and any non-linear components in the fibre-optic link such as a directly modulated laser can cause spectral re-growth of a strong input signal, interfering with a weak neighbouring channel. Hartmann et al [1-2] have reported transmission of single channel wireless data over multi-mode fibre (MMF) using uncooled 1300 nm DFB lasers without feed-forward linearisation. Previously we reported a feed-forward linearisation system which substantially enhanced the spurious-free dynamic range [3]. In this paper, we demonstrate for the first time the transmission of multi-channel broadband 11 Msymb/s QPSK modulated wireless signals centred around 2.4 GHz over 2.2 km single-mode fibre (SMF) with feed-forward linearisation intended for wireless LAN applications.

Experimental Arrangement
Figure 1 shows the overall transmission experimental arrangement with feed-forward linearisation. The wavelengths of the uncooled Lasers 1 and 2 were 1550 nm and 1570 nm, respectively. The Vector Signal Generator (VSG) provided the two 11 Msymb/s QPSK channels, A and B, at 2.434 GHz and 2.412 GHz, respectively. Channels A and B were combined in the microwave combiner before being input to the optical feed-forward transmitter. Channel A input power was fixed at +13 dBm throughout and Channel B input power varied. The aim of the experiment was to investigate how the spectral re-growth caused by the high-power Channel A would interfere with the neighbouring Channel B whose power was varied from -25 dBm to +13 dBm. The effectiveness of the feed-forward linearisation in the suppression of the spectral re-growth was also examined.

Figure 1: Experimental arrangement.

The detailed working principle of the feed-forward linearisation has been previously reported [3]. The key point is that the optical output of Laser 2 replicates the distortion products generated by Laser 1 with 180 degree phase shift and without the main modulated signal. Therefore when the outputs from Lasers 1 and 2 are detected by the photodiode, the distortion products are cancelled, leaving only the linearised signal from Laser 1. The feed-forward could be enabled or disabled by simply connecting or disconnecting Laser 2 output from the optical coupler. The output from the optical feed-forward transmitter was transported over a representative 2.2 km length of SMF (dispersion 17 ps/nm/km). Finally the linearised modulated signal at the output of the photodiode was amplified and detected using a Vector Signal Analyser (VSA).

Experimental Results
To illustrate the effectiveness of our system in suppressing spectral re-growth of Channel A caused...
by the non-linearity of Laser 1, the RF spectra of the two transmitted channels were measured with the feed-forward disabled and enabled as shown in Figure 2. When the feed-forward was disabled, the generated spectral re-growth from Channel A split into the frequency band of the neighbouring Channel B. When the feed-forward was enabled, the spectral re-growth was suppressed by at least 9 dB. Also with the spectral re-growth suppressed, the spectrum of Channel B can be seen more clearly. The quality of the measured eye-diagrams of the weaker Channel B were also affected by Channel A spectral re-growth. The eye-diagrams were measured with the VSA set to the centre frequency of Channel B at 2.412 GHz and selecting a 20 MHz wide channel filter and are shown in Figure 3.

With the feed-forward enabled, the eye-diagram had a wider opening compared to when the feed-forward was disabled. Only the in-phase eye-diagrams are shown in Figure 3 since the corresponding quadrature-phase ones were very similar. The error vector magnitude (EVM) and the signal-to-noise ratio (SNR) for Channel B were also measured in the presence of Channel A whose input power was fixed at +13 dBm throughout and the results are shown in Figure 4. The EVM decreased and SNR increased with increasing Channel B input power. At -20 dBm, the feed-forward reduced the EVM by 5 % and increased the SNR by 2 dB. The IEEE802.11b standard requires that the EVM not exceed 35 % and it can be seen in Figure 4 that without the feed-forward, Channel B would not be able to comply with this requirement for input levels below -23 dBm, whereas with feed-forward the specification is met for channel B levels as low as -26 dBm.

Finally the input powers of both Channels A and B were set equal at +13 dBm and the measured RF spectra in Figure 5 show that with the feed-forward disabled, there was strong intermodulation distortion caused by the two high input power signals directly modulating Laser 1 and any low-power signals in the next neighbouring channel frequency bands would have been severely degraded. With feed-forward enabled, the intermodulation distortion was suppressed by more than 10 dB.

Conclusions
For the first time we have used feed-forward linearisation in the transmission of multi-channel broadband QPSK signals around 2.4 GHz over 2.2 km SMF. The spectral re-growth of the +13 dBm Channel A has been reduced by 9 dB resulting in a 5% reduction in the EVM of the neighbouring -23 dBm Channel B. Intermodulation distortion has also been suppressed by 10 dB when both Channels A and B were set equal at +13 dBm. The results suggest that our feed-forward system can make practical multi-channel radio-over-fibre systems for wireless LAN applications.

References
[1] P. Hartmann et al; Vol 2, Laser 5.3.6, ECOC 2002