Pilot-Aided Channel Estimation in WCDMA on a Radio-over-Fibre Channel

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Abstract *In this paper the impact of a Radio-over-Fibre optical sub-system on the performance of Wideband Code Division Multiple Access is evaluated. The study investigates the use of pilot-aided channel estimation to compensate for the optical sub-system non-linearities in the presence of AWGN. The results show that pilot-aided (optical) channel estimation is an effective method of compensating for the optical sub-system impairments. It is found that there is always a suitable pilot power level which minimises the system* Bit *Error Rate (BER) performance.*

Keywords*:* RoF, WCDMA, AWGN, CPICH, Channel Estimation.

1-Introduction

Radio-over- Fibre (RoF) is a technology by which information bearing signals using RF carries are distributed by means of optical components and techniques. Better coverage and increased capacity, centralised upgrading and adaptation, higher reliability and lower maintenance costs, support for future broadband applications, and economic access to mobile broadband are among the most important advantages of RoF [1,2]. However, RoF systems are vulnerable to non-linearities in the optical subsystem that cause degradation of the system BER performance. Normally, these effects are expressed as AM-AM and AM-PM characteristics; the former is an amplitude transfer function while the latter is a phase transfer function.

Estimating the RF channel is an important function of a digital receiver because the transmitted data are subject to amplitude distortion and phase rotation due to RF channel variations. In order to compensate for the RF impairments, the phase rotation needs to be estimated. Normally, this is facilitated by using code-multiplexed or time-multiplexed pilot signals [3, 4].

In this paper, the impact of the optical sub-system non-linearities, as defined by the AM-AM/PM characteristics, on the performance of a downlink WCDMA is studied. Results for the system BER performance are presented for the AWGN case when a code-multiplexed Common PIlot CHannel (CPICH) is used to estimate the phase rotation introduced by the optical sub-system. The optimum Pilot Power corresponding to minimum BER is identified.

2-Simulation Model

In order to evaluate the effects of the optical sub-system on WCDMA in an AWGN channel, computer simulations were carried out based on the system model presented in Figure 1. The data are modulated and spread according to the data rate used. The channelisation codes are chosen from an orthogonal set of Walsh Hadamard codes. The data and pilot channels are combined in a QPSK constellation where the pilot channel uses a fixed symbol rate signal i.e. spreading factor=256 and bit rate=30 Kbps [5-6]. In this arrangement the total power, which is the sum of the powers of all spread signals including the pilot signal, is divided proportionally between pilot signal and users. This can be represented mathematically as

$$\frac{P_p}{P_u} = \frac{R P_t}{(1-R)P_t} = \frac{R}{(1-R)} \qquad (1)$$

where P_t is the total power, P_p is the pilot power, $R = P_p / P_t$ is the ratio of the pilot power to the total power,

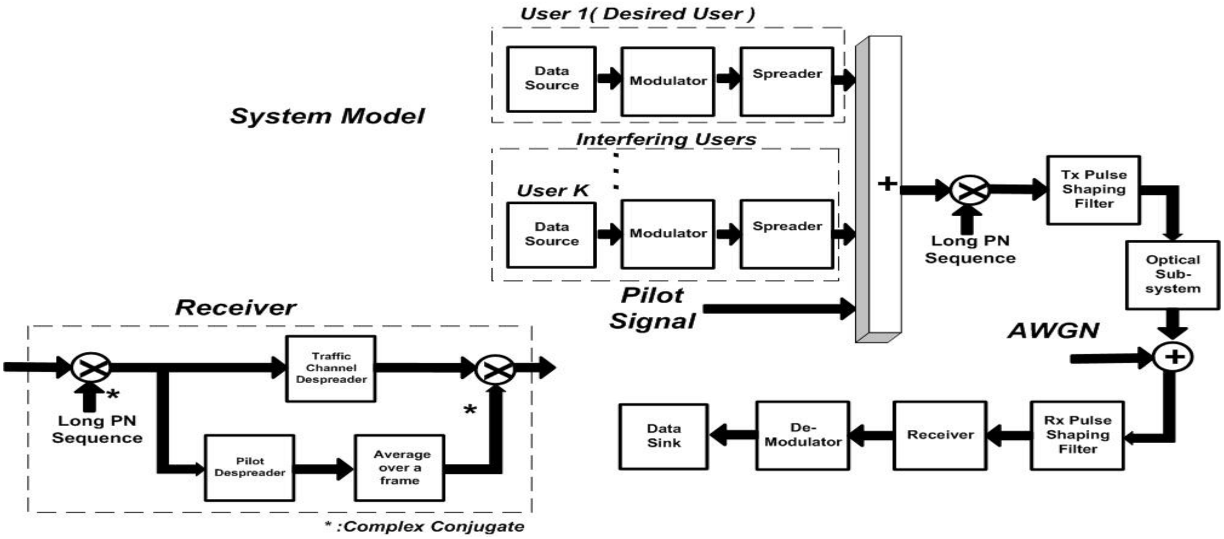
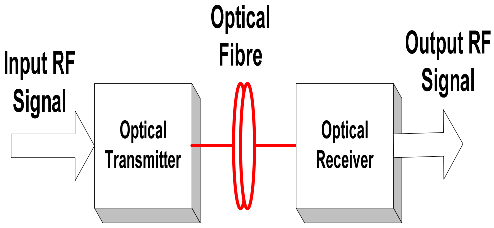


Figure 1 *WCDMA System Simulation Model*

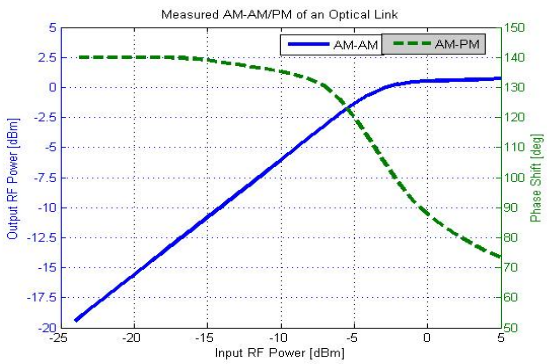
and P_u is the total power of all the users. Also, P_u is divided equally among all the users. The resultant signal is then chip-by-chip multiplied by a complex long PN sequence, filtered by a transmit Root-Raised Cosine (RRC) filter (rolloff=0.22 and number of taps= 64), and then passed to the optical sub-system. The optical sub-system, which has an overall gain of unity and shown in Figure 2-a, consists of a laser diode, a 2.2 km length of single-mode fibre, and a PIN diode for the photo-detector. The AM-AM/PM characteristics correspond to measured results from [7] are reproduced in Figure 2-b. After passing through an RF AWGN channel and filtered by the receive RRC filter, the received signal according to Figure 1-b is first multiplied by the complex conjugate of the long PN sequence and subsequently the pilot signal is extracted and averaged over a WCDMA frame period corresponding to 10 ms. The complex conjugate of the channel estimate multiplies the intended user's signal in order to compensate for the distortion introduced by the optical sub-system's non-linearities. The signal is then demodulated and finally the received data bits are compared with those transmitted. The simulation parameters and conditions are summarised in Table 1.

3- Results and Discussion

Figure 3 plots BER versus E_b / N_o for different values of the ratio R at different Output Backoff (OBO) levels.



(a)



(b)

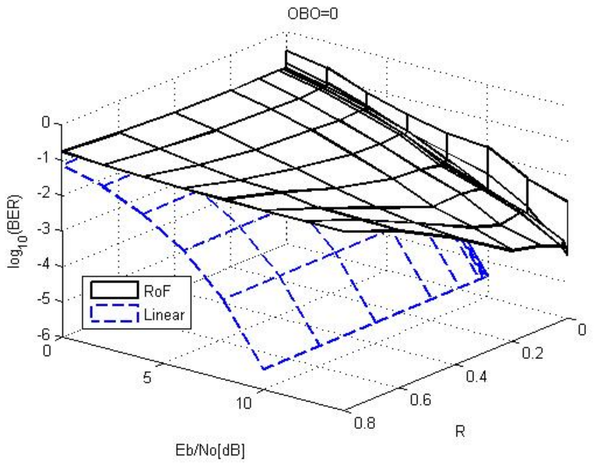
Figure 2 *a: Optical Sub-system Model, b: AM-AM / PM Characteristics*

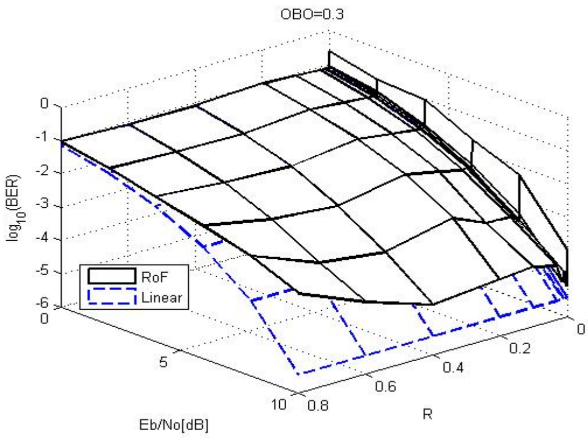
Table 1 *RoF-WCDMA Simulation Conditions and Parameters*

Parameter	**Value**	**Symbol**
Spreading Factor	64	SF
Output Back-off	0, 0.3, 3 dB	OBO
Number of Transmitted Frames	100	N_f
Frame Length	10 ms	T_f
Channel Data Rate	120 kbps	R_b
Roll-off Factor	0.22	α
Channel Type	AWGN	-
Ratio of Pilot Power to Total Power	0,0.00001,0.0001,0.001,0.01, 0.015,0.03,0.1,0.20,0.4,0.6,0.8	R
Estimation Level (Averaging over)	Frame	-
Modulation	QPSK	-

The plots are shown in a 3-D grid in order to identify the minimum BER position. Also shown in Figure 3 are theoretical BER curves for QPSK in AWGN.

Table 2 shows Input Backoff (IBO) levels, phase deviations, and optimum Total Degradations along with corresponding R values at BER=1e-3 for different OBO levels. The Total Degradation (TD) for a given BER





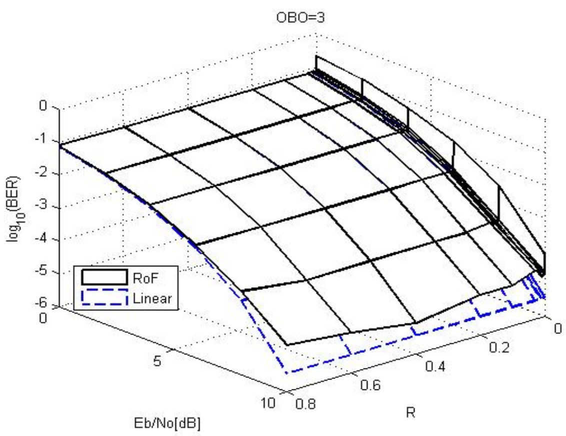


Figure 3 *Uncoded BER vs. Eb/No and Pilot Power Ratio (R) for RoF-WCDMA in AWGN Channel at: (a) 0, (b) 0.3, and (c) 3 -dB OBO*

Table 2 *IBO, phase deviation, optimum Total Degradation and corresponding R at BER=1e-3*

OBO (dB)	**IBO** (dB)	**Phase deviation** (degrees)	**Total Degradation** (dB)	**R**
0	0	66.7	3.5	< 10%
0.3	6.2	46.7	0.4	< 10%
3	11	13.5	3	< 10%

is defined as [8]

$$T_d = (E_b/N_o)_{NL} - (E_b/N_o)_L + OBO \qquad (2)$$

where $(E_b/N_o)_{NL}$ is the required signal-to-noise ratio per bit for the non-linear RoF-WCDMA system and $(E_b/N_o)_L$ is the signal-to-noise ratio per bit for the linear WCDMA system at a given BER.

In the non-linear RoF-WCDMA system, unlike the linear system, orthogonality of the wanted user's spreading code to that of the pilot signal and also to each spreading code of other users is lost. When R is small, the Pilot Power is low and the Multi-User Interference (MUI) is high which gives a very noisy estimate of the channel impairment. Hence, for this condition the system BER degrades rapidly. When R is large, the Pilot Power is high while the MUI is lower. Normally, this would provide a good channel estimate however the additional multiple access interference provided by the pilot degrades the channel estimate. For this condition the system BER degrades but not as rapidly as the case when R is too small. The interaction of the Pilot Power and MUI clearly leads to an optimum value for R which minimises the BER. This can be seen from Figure 3 and Table 2, in which for $R < 0.1$ an optimum performance can be achieved. As R deviates from the optimum value, the TD increases. For example, at $R = 0.2$, we incur additional TDs of 1.1, 0.3, and 0.15 dB in comparison with the optimum case for OBO values 0, 0.3, and 3 dB, respectively.

4-Conclusion

In this paper we investigated the impact of an optical sub-system's non-linearities on the system BER performance of a RoF–WCDMA system over an AWGN channel. The results demonstrate that pilot-aided channel estimation is an effective technique for equalisation of the signal degraded by the optical channel's impairments. Also, it was shown that by increasing R from 0.1 (optimum case) to 0.2 the TD increased by 1.1, 0.3, and 0.15 dB for OBO values 0, 0.3, and 3 dB, respectively. The achievable optimum performance depends on the OBO and R values, however there always exists a value of R which minimises the BER performance. The performance of WCDMA in a multi-path fading channel both for convolutional and turbo coded systems is the subject of further investigation by the authors.

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