Abstract

Discrete multitone transmission is a high performance technique which lends itself to efficient implementation. The paper focuses on the practical aspects of clock synchronization in that context. Different methods for adapting the sampling clock in the receiver are discussed and different frequency tracking loops are compared. The theoretical analysis is supported by simulation results.

Key words: Clock recovery, Synchronization, Signal interference, Multichannel transmission, Control loop.

I. INTRODUCTION

Discrete multi-tone (DMT) transmission is an emerging transmission technique due to its high performance at comparatively low implementational cost [2, 4]. A basic DMT transceiver is shown in Figure 1.

This contribution focuses on the practical aspects of synchronization in DMT transmission. Symbol synchronization is not a crucial issue thanks to the guard-interval whereas imperfect clock synchronization leads to inter-channel interference (ICI).

First the ICI-error will be quantified, followed by a simple way of detecting a clock frequency offset. Different methods for adapting a receiver's sampling clock to a given transmitter clock are discussed. Finally two different frequency tracking loops are compared, simulation results and possible control parameter sets are given.

Whenever we say transmitter and receiver we mean transmitter and receiver of different DMT transceivers.
because it would not make sense to use different sampling clock frequencies for either direction within one single transceiver.

II. ICI-ERROR

Let us assume that the transmit sampling frequency $f_T$ differs slightly from the receive sampling frequency $f_R$ such that $f_T = (1 + \Delta_f) f_R$. This will cause transmitter and receiver to drift away from each other and the orthogonality between the received carriers will be lost. The latter effect will now be quantified in terms of a signal to noise ratio (SNR) on each carrier.

The discrete Fourier transform $X_k(n)$ of a real cosine-wave with frequency $f_k$, phase $\phi_k$ and amplitude $a_k$ 

$$x_k(t) = a_k \cos(2\pi f_k t - \phi_k),$$

sampled at a rate $f_T$ is:

$$X_k(n) = \frac{a_k}{2} \exp \left[ j \left( \frac{N-1}{N} (N \frac{f_k}{f_T} - n) - \phi_k \right) \right]$$

$$+ \frac{a_k}{2} \exp \left[ -j \left( \frac{N-1}{N} (N \frac{f_k}{f_T} + n) - \phi_k \right) \right].$$

Substitution into eq. (1) yields:

$$X_k(n) = \frac{a_k}{2} \exp \left[ j \left( \frac{N-1}{N} ((1 + \Delta_f) n - \phi_k) \right) \right]$$

$$+ \frac{a_k}{2} \exp \left[ -j \left( \frac{N-1}{N} ((1 + \Delta_f) n + \phi_k) \right) \right].$$

Choosing $k = n$ yields the received signal portion $X_n^+(n)$ of the transmit signal with carrier index $n$ when omitting the second part of eq. (2) which stems from negative frequencies:

$$X_n^+(n) = \frac{a_n}{2} \exp \left[ j \left( \frac{N-1}{N} (\Delta_f n - \phi_n) \right) \right]$$

$$\frac{\sin \left[ \frac{\pi}{N} (\Delta_f n) \right]}{\sin \left[ \frac{\pi}{N} (\Delta_f n) \right]}.$$