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Symbol synchronisation in a DMT system with crosstalk interference
Synchronisierung von Symbolen in einem DMT-System mit Übersprechstörung
Synchronisation de symboles dans un système DMT avec diaphonie

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Description

Technical area.

[0001] A telecommunications transmission system using a DTM system as multicarrier system and having at least two VDSL systems, each comprising a pair of modems, said at least two VDSL systems belonging to a single binder group common to both VDSL systems, a method in said DMT system for keeping DMT frames aligned to the same frame timing.

State of the art.

[0002] DMT is a multi-carrier technique standardised and well known for a man skilled in the art used for high bit-rate data transmission on twisted-pair lines, such as subscriber loops for telephony.

[0003] In US 5,812,523 describes a method of demultiplexing OFDM signals and a receiver for such signals. More particularly the method is concerned with synchronization in an OFDM receiver. A signal is read into a synchronization unit, in the time domain, i.e., before fourier transforming the signal by means of an FFT processor. In the synchronization unit, a frame clock is derived for triggering the start of the FFT process and for controlling the rate at which data is supplied to the FFT processor. For OFDM reception, it is vital that the FFT process commences at the right point in time. Once the frame clock has been recovered, a frequency error can be estimated by the synchronization unit. The frequency error is used to control an oscillator which generates a complex rotating vector which is, in turn, multiplied with the signal to compensate for frequency errors. The method can be used both with OFDM systems in which symbols are separated by guard spaces, and with OFDM systems in which symbols are pulse shaped. Our invention has put in to practice a new method which is partly based on this earlier known method.

[0004] The document EP-A-0 917 315A describes relates art. The method disclosed in this document is based on energy variations. It only works for TDD systems.

Technical problem.

[0005] One problem that is always present is the signal cross-talk between pairs located in the same cable bundle. The cross-talk is usually described as two components, NEXT and FEXT. NEXT (Near End X-Talk) is the interference from other transmitters in the same end as the receiver. FEXT (Far End X-Talk) is the interference from other transmitters in the opposite end of the line.

[0006] DMT is a digital transmission technology relying on the orthogonality between carriers. The upstream and down-stream transmission is done on separate sets of carriers. Thus, NEXT is associated with transmission in the opposite direction and FEXT with transmission in the same direction as the received data. NEXT is usually the strongest interference signal, since it is generated close to a receiver that is receiving a weak signal.

[0007] The orthogonality is the best means to reduce the influence of NEXT. As long as the DMT frames are aligned to the same frame timing, the orthogonality holds and adjacent carriers can be used for different transmission directions without any capacity loss due to NEXT. This synchronisation has been posed as a problem for operators to implement, especially in an "unbundled" environment, where different operators share the same cable bundles.

Technical solution.

[0008] In accordance with the invention the solution is what is stated in the claims.

Advantages.

[0009] The new technique in this invention is a step towards the synchronized DMT, again allowing the use of adjacent carriers without any NEXT influence and the full capacity of the synchronized DMT. It is an adaptive timing technique that is easy to implement and does not need any extra communication between modems or between operators' installations.

[0010] The foregoing and other features of the present invention will be better understood from the following description with reference to the accompanying drawings, in which:

Figure 1 illustrates, in schematic form, two VDSL systems operating in the same cable with corresponding NEXT and FEXT cross-talk.

Figure 2 illustrates, in schematic form, a DMT time-domain frame format.

Figure 3 illustrates, in schematic form, an Correlator block diagram.

Figure 4 illustrates, in schematic form, a DMT frame correlation without cross-talk.

Figure 5 illustrates, in schematic form, an Cross correlation of DMT signal with DMT cross-talk er at a 3 dB lower power.

[0011] In order to facilitate an understanding of the present invention a glossary of terms used in this patent specification is provided below:

VDSL -- Very high rate Digital Subscriber Line
NEXT -- Near End crosstalk
FEXT -- Far End crosstalk
DMT -- Discrete Multitone, a multicarrier system using Discrete Fourier Transforms to create and demodulate individual carriers.
[0012] Turning first to fig 1 there is illustrated a principal drawing of a situation where two VDSL systems operating in the same cable with corresponding NEXT and FEXT cross-talk. Fibre cables (not shown) feeding neighbourhood Optical Network Units (ONUs) and last leg premises connections by existing or new copper. VDSL transmits high-speed data over short reaches of twisted-pair copper telephone lines, with a range of speeds depending upon actual line length. VDSL is also a type of modem technology, enabling high-speed delivery of data, audio, and video in a digital form over the existing telephone infrastructure (copper twisted-pair phone lines called the local loop) which connects the customer premises and the carrier’s central office. The basic idea behind all VDSL technology is that a special modem is attached to each end of the copper phone line, i.e. one modem at the customer premises and another one at the central office. The phone line is then exploited with the help of modulating techniques. In our invention we use Discrete Multi-Tone (DMT) as the multi-carrier modulating technology.

[0013] However is there always signal cross-talk between pairs located in the same cable bundle.

[0014] There are basically two different forms of crosstalk in neighbouring copper pairs in the same cable: near-end crosstalk (NEXT) and far-end crosstalk (FEXT). NEXT is usually the strongest interference signal and occurs at the central office (base station)/optical network side when the weak upstream signal, is disturbed by strong downstream signals. FEXT is crosstalk from one transmitted signal to another in the same direction and appears at the opposite end of the line, which is the premise side.

[0015] DMT is our transmission technology, which is well known for a man skilled in the art. Turning now to fig 2 there is shown the frame format of the time-domain DMT signal. The symbol itself is extended by a cyclic extension (prefix and suffix). Shaping of the outer parts of the extension is used to reduce the out-of-band interference caused by the transmitter.

[0016] The extension is created as copies of parts of the DMT symbol, as shown in Figure 2. Therefore, there is a strong correlation between parts of the time-domain signal built into the frame. The correlation of the time-domain signal by a delayed copy will then show peaks when a certain part of the frame passes the receiver. Due to the small piece of the frame length that is used for the correlation, only relatively strong signals will be clearly distinguishable. However, these are the only cross-talk signals that will cause any serious problems for the receiver. Averaging by using several frames in the correlation estimation will improve the quality of the estimate.

[0017] The invention uses the inherent property of DMT signals and that part of the signal is correlated in terms of cyclic extensions.

[0018] Via auto-correlation on the received time-domain DMT signal the time mis-alignment of cross-talkers can be estimated using the correlator shown in figure 3.

[0019] In fig 3 the received sampled DMT signal, x(k), is the sum of the signal that is transmitted from the opposite end of the line and cross-talk signals that originate from other DMT signals transmitted on neighbouring pairs in the same cable.

[0020] The received signal x(k) is divided into two branches. One of the branches delays the signal by 2N samples corresponding to the length of one DMT symbol. A new signal, y(k), is then created as the product of the two signals x(k) and x(k-2*CE). The signal y(k) is divided into two branches whereas one branch delays the signal CE samples, corresponding to the length of the total cyclic extension of the DMT frame. A new signal, w(k), is created as the difference y(k) - y(k-CE). The signal, w(k), is finally fed into an accumulator unit to create the correlation signal c(k).

[0021] The implementation of the correlation algorithm will be substantially simplified by using only the sign bit of the input signal X(k).

[0022] If there are no cross-talkers present, the correlation sequence c(k) will have the principal shape as depicted in figure 4.

[0023] If, however, there are DMT cross-talk signals added to the signal, they will contribute to the auto-correlation with the same kind of correlation peaks located according to the frame timing. If the individual signals are uncorrelated, the correlation of a sum of signals equals the sum of the correlations of the individual signals. If the DMT receiver has knowledge of its own frame boundaries, it can easily determine which correlation peaks correspond to the desired signal and the crosstalk signals, respectively. An example is shown by Figure 5.

[0024] The time shift of the correlation peaks of the cross-talkers is a measure of the time mis-alignment relative to the desired signal. The amplitude of each cross-talk peak is a relative measure of the power of the cross-talker.

[0025] At start-up the receiver makes a correlation on the signal including the cross-talkers. Assuming that all cross-talkers are aligned to common frame timing, they will all have their correlation peaks located in a small range of time. The starting-up modem, therefore, should use the correlation information to align its own frame timing to the cross-talkers. If every starting-up modem uses this method, all modems that cause interference in each other’s receivers will become aligned to the same frame timing.

[0026] The method estimates the time mis-alignment and power of cross-talk DMT signals added to a received DMT signal and the estimate is used by the modem to synchronise its own frame timing to a main cross-talkers frame timing.

[0027] The correlation between the received signal and a delayed copy of the received signal is used. Correlation maxima detection enables to determine the frame boundaries of different DMT components of the
received signal.

[0028] It is important to mention that the method uses the inherent property of DMT signals and that part of the signal is correlated, in the time domain, in terms of cyclic extensions.

The method further comprising the step that the time mis-alignment, which illustrates in figure 5, of the cross-talk signals estimates as the distance between the correlation maximum corresponding to the desired signal (known location) and other correlation maxima.

[0029] As can bee seen in fig 5 amplitude of a correlation maximum is a relative measure of the power of the corresponding cross-talker.

[0030] The method further comprising the step that when the time offset of the cross-talk is estimated at the VTU-O, this information will be used to adjust its clock and frame boundaries to align with the cross-talker and hence orthogonality is achieved and the distortion is minimized.

[0031] The method further comprising the step that if the auto-correlation peak amplitude of the cross-talk signal is low the VTU-O does not align clock and frame boundaries since the cross-talker then do not significantly contribute to the distortion and hence a threshold level will be used.

Claims

1. A method for keeping DMT frames aligned to the same frame timing, for use in a telecommunications transmission system using a DMT system as multi-carrier system and having at least two VDSL systems, each comprising a pair of modems, said at least two VDSL systems belonging to a single binder group common to both VDSL systems, characterised by the steps of:

   a) effecting a correlation between a received DMT signal comprising DMT symbols having cyclic extensions and a delayed copy of the received signal; and

   b) detecting correlation maxima which determine the frame boundaries of different DMT components of the received signal; and

   c) estimating the time mis-alignment from the correlation maxima; and

   d) using the estimate by the modem to synchronise its own frame timing to a main cross-talkers frame timing.

2. A method, as claimed in claim 1, characterised in that the method uses the correlation between the cyclic extension of a DMT symbol and the end of the DMT symbol.

3. A method, as claimed in claim 1, characterised in that the method further comprises the step that the time mis-alignment of the cross-talk signals is estimated from the distance between the correlation maximum corresponding to the desired signal and other correlation maxima.

4. A method, as claimed in claim 3, characterised in that the method further comprises the step of estimating the relative power of the corresponding cross-talker from the amplitude of a correlation maximum.

5. A method, as claimed in claim 3, characterised in that the method further comprises the step that when the time offset of the cross-talk is estimated at the VTU-O, this information will be used to adjust its clock and frame boundaries to align with the cross-talker and hence orthogonality is achieved and the distortion is minimized.

6. A method, as claimed in claim 3, characterised in that the method further comprises the step that if the auto-correlation peak amplitude of the cross-talk signal is under a predetermined threshold level the VTU-O does not align clock and frame boundaries since the cross-talker then do not significantly contribute to the distortion.

7. Use of a method as claimed in any previous claim, by every modem when starting-up in a system, for aligning all modems to the same timing.

Patentansprüche

1. Verfahren zum Ausgerichtethalten von DMT-(Discrete Mehrträger Übertragung)-Rahmen mit der gleichem Rahmentaktung zur Verwendung in einem Telekommunikationsübertragungssystem unter Nutzung eines DMT-Systems als Mehrträgersystem und mit zumindest zwei VDSL-Systemen, von denen ein jedes ein Paar von Modems aufweist, wobei zumindest zwei VDSL-Systeme zu einer einigen Verbundgruppe gehören, die gleich für die VDSL-Systeme ist, gekennzeichnet durch die folgenden Schritte:

   a) Bewirken einer Korrelation zwischen einem empfangenen DMT-Signal, das DMT-Symbole aufweist mit zyklischen Erweiterungen und einer verzögernten Kopie des empfangenen Signals; und

   b) Detektieren eines Korrelationsmaximums, das die Rahmengrenzen von unterschiedlichen DMT-Komponenten des empfangenen Signals bestimmt; und

   c) Schätzen der zeitlichen Fehlaufrichtung aus
dem Korrelationsmaximum; und
d) Nutzen der Schätzung durch das Modem
zum Synchronisieren seiner eigenen Rahmen-
taktung zu einer Haupt- bzw. Netz-Neben-
sprechrahmentaktung.

2. Verfahren nach Anspruch 1, dadurch gekenn-
zeichnet, dass das Verfahren die Korrelation zwi-
schen den zyklischen Erweiterungen eines
DMT-Symbols und das Ende des DMT-Symbols
nutzt.

3. Verfahren nach Anspruch 1, dadurch gekenn-
zeichnet, dass das Verfahren weiter den Schritt
aufweist, dass die zeitliche Fehlausrichtung bzw.
Taktungsfehlausrichtung der Nebensprechsignale
geschätzt wird aus dem Abstand zwischen dem
Korrelationsmaximum, das dem erwünschten Si-
gnal entspricht, und anderen Korrelationsmaxima.

4. Verfahren nach Anspruch 3, dadurch gekenn-
zeichnet, dass das Verfahren ferner den Schritt
aufweist, dass die zeitliche Fehlausrichtung bzw.
Taktungsfehlausrichtung der Nebensprechsignale
geschätzt wird aus dem Abstand zwischen dem
Korrelationsmaximum, das dem erwünschten Si-
gnal entspricht, und anderen Korrelationsmaxima.

5. Verfahren nach Anspruch 3, dadurch gekenn-
zeichnet, dass das Verfahren weiter den Schritt
aufweist, dass wenn ein Zeitversatz des Neben-
sprechens bei dem VTU-O geschätzt wird, diese In-
formation genutzt wird für das Einstellen seiner Tak-
tung bzw. Taktgeber und der Rahmengrenzen zum
Ausrichten mit dem Nebensprecher, wobei somit ei-
e Orthogonalität erreicht wird und die Störung bzw.
Verzerrung minimiert wird.

6. Verfahren nach Anspruch 3, dadurch gekenn-
zeichnet, dass das Verfahren ferner den Schritt
aufweist, dass wenn die Autokorrelationsspitzen-
amplitude des Nebensprechsignals unter einem
vorbestimmten Schwellenwertpegel ist, das VTU-O
den Taktgeber bzw. die Taktung und die Rahmengrenzen
durch Ausrichten mit dem Nebensprecher, wobei somit ei-
e Orthogonalität erreicht wird und die Störung bzw.
Verzerrung minimiert wird.

7. Verwendung eines Verfahrens nach einem der vor-
hergehenden Ansprüche durch jedes Modem,
wenne es in einem System hochgefahren bzw.
gestartet wird, und zwar für das Ausrichten aller Mo-
dems mit der gleichen Taktung bzw. Zeitsteuerung.

Revendications

1. Procédé pour maintenir alignées des trames DMT
sur la même synchronisation de trame, destiné à
être utilisé dans un système de transmission de té-
lécommunication utilisant un système DMT en tant
que système multi-porteuse et comportant au
moins deux systèmes VDSL, comprenant chacun
deux modems, lesdits au moins deux systèmes
VDSL appartenant à un groupe de liaison unique
commun aux deux systèmes VDSL, caractérisé par
les étapes suivantes:
a) effectuer une corrélation entre un signal
DMT reçu comprenant des symboles DMT
ayant des extensions cycliques et une copie re-
tardée du signal reçu ;
b) détecter des maxima de corrélation qui dé-
terminent les limites de trame de composantes
DMT distinctes du signal reçu ;
c) estimer le décalage temporel à partir des maxima de corrélation ; et
d) utiliser l’estimation par le modem pour syn-
chroniser sa propre synchronisation de trame
sur une synchronisation de trame principale d’émetteurs de diaphonie.

2. Procédé selon la revendication 1, caractérisé en
ce que le procédé utilise la corrélation entre l'exten-
sion cyclique d'un symbole DMT et la fin du sym-
bole DMT.

3. Procédé selon la revendication 1, caractérisé en
ce que le procédé comprend en outre l'étape selon
laquelle le décalage temporel des signaux de diaphonie est estimé à partir de la distan-
ce entre le maximum de corrélation correspondant
au signal désiré et d'autres maxima de corrélation.

4. Procédé selon la revendication 3, caractérisé en
ce que le procédé comprend en outre l'étape consistant à estimer la puissance relative de l'émetteur
de diaphonie correspondant à partir de l'amplitude
d'un maximum de corrélation.

5. Procédé selon la revendication 3, caractérisé en
ce que le procédé comprend en outre l'étape selon
laquelle, quand le décalage temporel de la diapho-
nie est estimé au niveau du VTU-O, cette informa-
tion est utilisée pour régler son horloge et ses limi-
tes de trame pour alignement avec l'émetteur de
diaphonie, d'où il résulte que l'orthogonalité est réa-
lisée et la distorsion est rendue minimale.

6. Procédé selon la revendication 3, caractérisé en
ce que le procédé comprend en outre l'étape selon
laquelle, si l'amplitude du pic d'auto-corrélation du
signal de diaphonie est en dessous d'un niveau de
seuil prédéterminé, le VTU-O n'aligne pas l'horloge
et les limites de trame puisque l'émetteur de diapho-
nie ne contribue pas alors de façon significative à
la distorsion.

7. Utilisation du procédé selon l'une quelconque des
revendications précédentes par tout modem, à l'initialisation d'un système, pour aligner tous les modems sur la même synchronisation.
Fig 2

DMT frame

prefix

suffix

Fig 3

Delay 2*N

x(k)

y(k)

X

Delay CE

w(k)

Accumulator

C(k)
Fig 4

Correlation peaks
DMT signal
(no crosstalk)
Fig 5

- Correlation peaks DMT signal
- Correlation peaks DMT crosstalk
- Misalignment

x 10^4