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(54) **CHANNEL ESTIMATOR FOR OFDM SYSTEM**

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H04J 11/00   (2006.01)

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370/206, 343, 480, 491; 375/147
See application file for complete search history.

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Primary Examiner—Ajit Patel
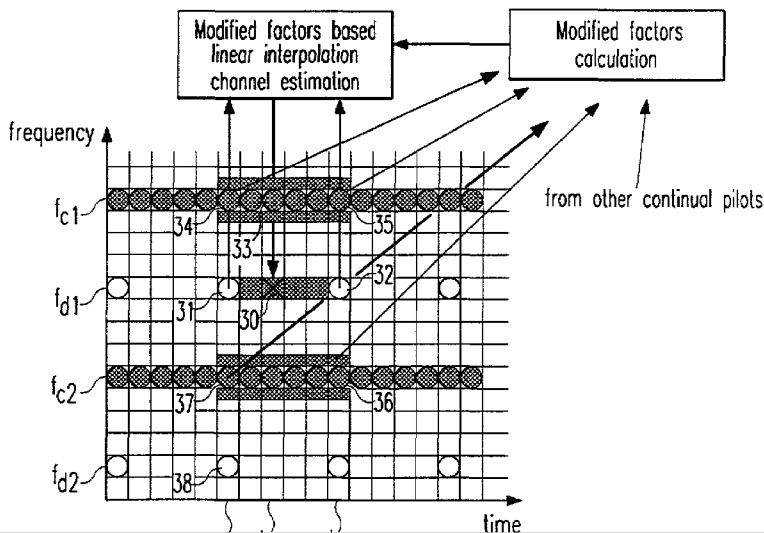*Assistant Examiner*—Steven A Blount
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Maier & Neustadt, P.C.

(57)   **ABSTRACT**

The present invention relates to a device **(10)** for receiving
signals in a wireless orthogonal frequency division multi-
plex (OFDM) system and to a channel estimation method in
such a system. The data symbols and pilot symbols are
transmitted in frequency subcarriers and timeslots, whereby
pilot symbols are transmitted in a continuous stream within
at least one frequency subcarrier. A channel estimation for a
data symbol is performed on the basis of received pilot
symbols using a filter including a common phase error
correction value from the continuous stream pilot symbol in
the same timeslot as the data symbol to be channel esti-
mated.

The present invention thereby enables a correct and efficient
channel estimation including a common phase error correc-
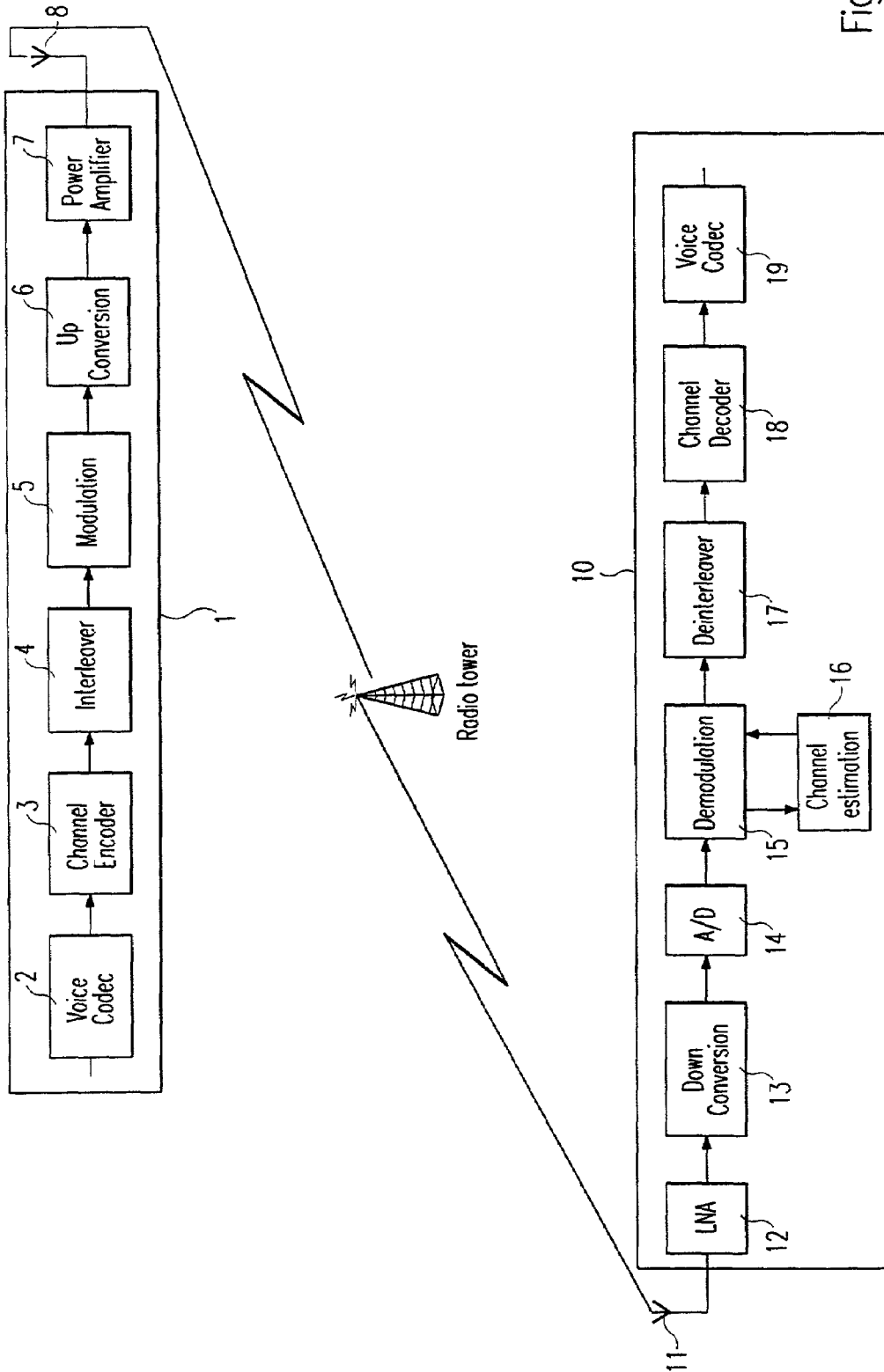tion to be performed.

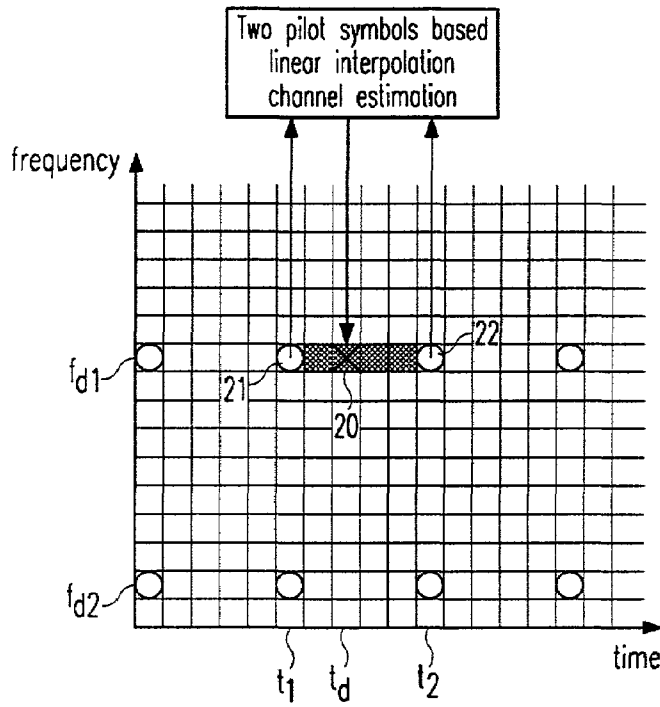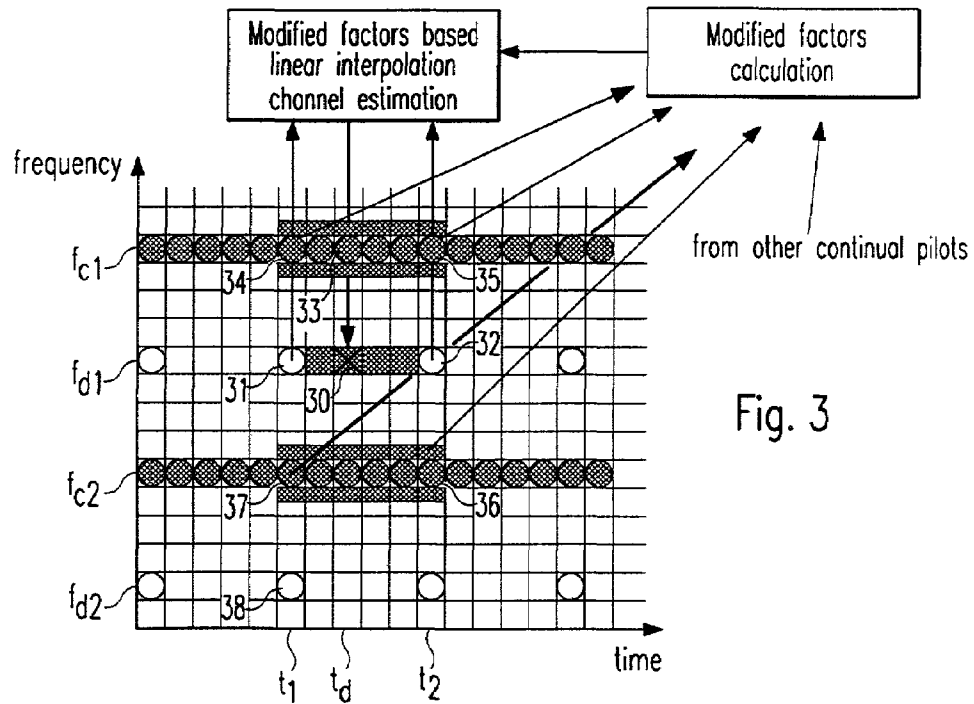**4 Claims, 2 Drawing Sheets**

Fig. 1

Two pilot symbols based
linear interpolation
channel estimation

frequency

f_{d1} — 21 — 20 — 22

f_{d2}

time

t_1 t_d t_2

Fig. 2

Modified factors based
linear interpolation
channel estimation

Modified factors
calculation

frequency

f_{c1} — 34 — 33 — 35

from other continual pilots

f_{d1} — 31 — 30 — 32

Fig. 3

f_{c2} — 37 — 36

f_{d2} — 38

time

t_1 t_d t_2

CHANNEL ESTIMATOR FOR OFDM SYSTEM

The present invention relates to the channel estimation in a wireless orthogonal frequency division multiplex (OFDM) system. Particularly, the present invention relates to a device for receiving signals in a wireless OFDM system and to a channel estimation method in a wireless OFDM system.

Wireless OFDM communication systems are systems, in which communication devices, as e.g. base stations, communicate with other devices, as e.g. mobile terminals, over a wireless communication link. In an OFDM system, the entire frequency bandwidth used for the transmission of signals is subdivided into a plurality of frequency subcarriers. Adjacent frequency subcarriers are respectively orthogonal to each other. Thus, very high data rate communication can be achieved in OFDM systems.

A transmission channel of an OFDM system can be characterised by a specific frequency subcarrier and a specific timeslot. A piece of information, such as a data symbol, to be transmitted in that specific transmission channel is mapped onto the frequency subcarrier in the specific timeslot. The data transmission in an OFDM system can therefore be represented by a time/frequency grid. In the frequency domain, adjacent transmission channels have respectively orthogonal frequency subcarriers.

On the receiving side of an OFDM communication link, as e.g. a mobile terminal receiving signals from a base station, a channel estimation is performed for each transmission channel or data symbol in order to optimise the demodulation in the receiver in view of the estimated channel quality. Hereby, a specific pilot symbol pattern is transmitted in the time/frequency grid of the OFDM communication link. The time/frequency location (frequency subcarrier and timeslot) of the pilot symbols as well as the pilot symbol itself are known to the receiver, so that the receiver is able to perform a channel estimation for data symbols transmitted in transmission channels different from the pilot symbols. A typical pilot symbol pattern with a plurality of pilot symbols placed in the frequency subcarrier/time grid of an OFDM system is shown in FIG. **2**. The frequency domain is subdivided into a plurality of frequency subcarriers and the time domain is subdivided into a plurality of timeslots. Each frequency subcarrier and timeslot define a transmission channel for the transmission of a data symbol or a pilot symbol. Pilot symbols are indicated by circles. In the example shown in FIG. **2**, pilot symbols are transmitted in the frequency subcarrier f_{d1} and in the frequency subcarrier f_{d2} in respectively equidistant timepoints. For example, in the timeslots t_1 $_{and}$ $_{t2}$, pilot symbols are transmitted on both frequency subcarriers f_{d1} and f_{d2}.

In the following, the principle of a standard channel estimation method in an OFDM communication system is described. An OFDM signal received in a receiving device of the OFDM system after a fast Fourier transformation for a frequency subcarrier x and a timeslot i can be represented by

$$r_{x,i} = s_{x,i} \times h_{x,i} + n_{x,i}$$

whereby $s_{x,i}$ is the transmitted data symbol, $h_{x,i}$ is the complex channel response and $n_{x,i}$ is the adaptive White Gaussian noise for the frequency subcarrier x and the timeslot i.

the received signals to perform a channel estimation at the frequency subcarrier/timeslot location of the pilot symbol. Assuming that the pilot symbols are located at the frequency carrier position x' and the timeslot position i', an initial channel estimation can be formed by

$$\hat{h}_{x,i} = \frac{r_{x',i'}}{s_{x',i'}}$$

In order to obtain the channel estimation values for the frequency subcarriers and the times lots located between the pilot symbols (in frequency and/or in time dimension), a filter is usually used. This filter can have several general forms, which include a one-dimensional form (in frequency or time), a two-dimensional form (in frequency and time), a two-one-dimensional form (first frequency and then time or vice versa) and the like. Further, the filter itself can have fixed or variable coefficients. A very simple example of an one-dimensional time filter based e.g. on a linear interpolation scheme is explained in FIG. **2**. In this case, the channel estimation for the transmission channel **20**, which is characterised by the frequency subcarrier f_{d1} and the timeslot t_d, is performed on the basis of the two pilot symbols **21** and **22** in the frequency subcarrier f_{d1} and timepoints t_1 and t_2, respectively. Therefore, transmission channel **20** to be estimated is transmitted on the same frequency subcarrier f_{d1} as the pilot symbols **21, 22**, so that only a one-dimensional time filter is necessary. Thus, the channel estimation for the transmission channel **20** can e.g. very simply be performed on the basis of a linear interpolation of the channel transmission properties of the received pilot symbols **21** and **22**.

However, all channel estimation algorithms proposed and used for OFDM communication systems as described above, do not take into account the effect of phase noise on the result of the channel estimation using received pilot symbols. The phase noise stems from the local oscillator in the receiver, which is a random pertubation of the phase of the steady sinusoidal waveform. There are two different kinds of phase noise. The first kind rotates the received signals by an amount, which is the same for all frequency subcarriers within one OFDM symbol (within one timeslot), but varies randomly from symbol to symbol, i.e. from timeslot to timeslot. This first kind of phase noise is called common phase error (CPE) and primarily results from the lower frequency components of the phase noise spectrum of the local oscillator. The second kind of phase noise is called intercarrier interference (ICI) which works like additive thermal noise and primarily results from the higher frequency components of the phase noise spectrum of the local oscillator. The CPE component caused by the phase noise is eliminated in known receiving devices by inserting a complex CPE correction module in an OFDM demodulator. Alternatively, the effect of the phase noise can be reduced by adapting a stable but expensive local oscillator. However, using a complex CPE correction module as an additional element or a stable and expensive local oscillator raises the entire costs and the constructional complexity.

The object of the present invention is therefore to provide a device for receiving signals in a wireless OFDM system and a channel estimation method in a wireless OFDM system, which allow the implementation of a simple but effective channel estimation algorithm with a simple construction.

which data symbols and pilot symbols are transmitted in frequency subcarriers and timeslots. The device according to the present invention comprises receiving means for receiving pilot symbols transmitted in a continuous stream within at least one frequency subcarrier and channel estimation means for performing a channel estimation for a data symbol on the basis of received pilot symbols using a filter including a common phase error correction value from the continuous stream pilot symbol in the same timeslot as the data symbol to be channel estimated.

Further, the above object is achieved by a channel estimation method in a wireless OFDM system according to claim **6**, in which data symbols and pilot symbols are transmitted in frequency subcarriers and timeslots and in which pilot symbols are transmitted in a continuous stream within at least one frequency subcarrier, whereby a channel estimation for a data symbol is performed on the basis of received pilot symbols using a filter including a common phase error correction value from the continuous stream pilot symbol in the same timeslot as the data symbol to be channel estimated.

Thus, the present invention proposes a channel estimation on the basis of received pilot symbols using a filter including a common phase error correction value. The filter can be any kind of filter. The common phase error correction value is obtained on the basis of the continuous stream pilot symbol in the same timeslot as the data symbol to be channel estimated. Thus, the wireless OFDM communication system of the present invention necessarily requires at least one continuous stream of pilot symbols in one of the plurality of frequency subcarriers. Some OFDM systems used in wireless communication or telecommunication scenarios have a high number of frequency subcarriers, so that using at least one entire frequency subcarrier for the transmission of a continuous stream of pilot symbols does not effect the data transmission capacity too much. It has to be noted that the term continuous stream of pilot symbols means that each of the consecutive symbols or timeslots of a respective frequency subcarrier carries a pilot symbol, so that a continuous stream of respectively succeeding pilot symbols is transmitted in that frequency subcarrier. Further, the common phase error is the same for all frequency subcarriers within one symbol or timeslot, so that using a phase error correction value from the pilot symbol of the continuous stream in the same timeslot as the data symbol to be channel estimated ensures that the phase error can be sufficiently reduced or even eliminated. Further, the present invention allows the integration of the common phase error correction into the channel estimation algorithm so that the overall processing complexity is reduced.

Advantageous features are claimed in the respective subclaims.

Advantageously, the receiving means is further adapted to receive distributed or scattered pilot symbols distributed or scattered among said frequency subcarriers and timeslots, whereby said channel estimation means performs said channel estimation on the basis of at least two of said distributed pilot symbols. In other words, besides the continuous stream of pilot symbols in at least one frequency subcarrier, further distributed pilot symbols are used. These distributed pilot symbols do not need to be in adjacent transmission channels and can have a regular or an irregular pattern, as long as the pattern is known to the receiving device performing the channel estimation. Additionally using pilot symbols from the pattern of distributed pilot symbols makes the channel

the channel estimation means may perform the channel estimation on the basis of at least two of said distributed pilot symbols in different timeslots using a time filter. Thus, a time filter on the basis of at least two pilot symbols having different timeslots is used together with the common phase error correction value from the continuous stream pilot symbol of the same timeslot as the data symbol to be channel estimated. Hereby, a very accurate and efficient channel estimation can be performed.

The channel estimation means advantageously calculates the common phase error correction value on the basis of the continuous stream pilot symbol in the same timeslot as the data symbol to be channel estimated and on the basis of the continuous stream pilot symbols respectively in the same timeslots as said at least two distributed pilot symbols. The at least two distributed pilot symbols are located in different timeslots so that a respective continuous stream pilot symbol can be found in the respective same timeslots. Then, the common phase error correction value is calculated on the basis of the continuous stream pilot symbol in the same timeslot as the data symbol to be channel estimated and on the basis of the at least two continuous stream pilot symbols in the same timeslots as the distributed pilot symbols. In this case, the common phase error correction value is advantageously calculated on the basis of common phase error ratios between said continuous stream pilot symbol in the same timeslot as the data symbol to be channel estimated and each of said continuous stream pilot symbols respectively in the same timeslot as said at least two distributed pilot symbols. Hereby, the common phase error ratios are implemented in the algorithm for calculating the channel estimation for the respective data symbol so that a simple and effective implementation of the entire channel estimation algorithm including a common phase error suppression is enabled.

The present invention is explained in more detail in the following description in relation to the enclosed drawings, in which

FIG. **1** shows a wireless OFDM communication system including a transmitting device and a receiving device,

FIG. **2** shows a subcarrier frequency and timeslot grid of a wireless OFDM communication system with a known pilot symbol pattern, and

FIG. **3** shows an example of a subcarrier frequency and timeslot grid of an OFDM communication system according to the present invention having at least one continuous stream of pilot symbols within one frequency subcarrier.

A wireless communication system comprising a transmitting device **1**, such as a base station, and a receiving device **10**, such as a mobile terminal, are shown in FIG. **1**. The wireless communication system is an OFDM system, in which data symbols are transmitted in frequency subcarriers and timeslots. The entire frequency range is subdivided into a plurality of frequency subcarriers. The transmitting device **1** comprises all necessary and known elements for the operation in a wireless OFDM communication system, such as a voice codec **2**, a channel encoder **3**, an interleaver **4**, a modulation means **5**, an upconversion means **6**, a power amplifier **7** and an antenna **8**. In case that the transmitting device **1** is part of a base station or a mobile terminal of the OFDM system, it further comprises all necessary elements for receiving signals and for processing the received signals.

Signals transmitted via the antenna **8** of the transmitting device **1** are wirelessly transmitted to a receiving device **10** of the wireless OFDM communication system, optionally with the support of an intermediate amplifying radio tower

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