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(54) Title: METHOD AND APPARATUS FOR PROVIDING PILOT SIGNALS IN OFDM FRAMES

(57) Abstract: In a telecommunication network, pilot signals are provided in OFDM (orthogonal frequency division multiplexing) frames to enable the SC-FDMA (the single-carrier frequency division multiple access) concept to work with the OFDMA concept in uplink substantially harmonically, wherein each OFDM frame comprises a predetermined plurality of OFDM symbols, and at least one pilot signal is placed in addition to other data and/or signals within at least one existing OFDM symbol of said predetermined plurality of OFDM symbols.

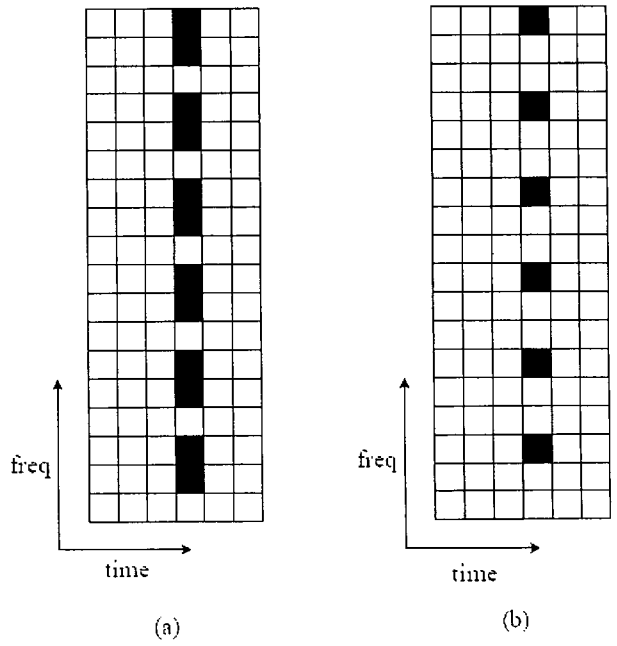


Figure 3

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Method and apparatus for providing pilot signals in OFDM frames

FIELD OF THE INVENTION

The present invention relates to a method of providing pilot signals in OFDM (orthogonal frequency division multiplexing) frames, each OFDM frame comprising a predetermined plurality of OFDM symbols, in a telecommunication network, and a computer program configured to perform such a method. Further, the present invention relates to a network element for a telecommunication network, comprising an OFDM generator configured to generate OFDM frames, each OFDM frame comprising a predetermined plurality of OFDM symbols, a pilot generator configured to generate pilot signals, and a transmitter configured to transmit said OFDM frames and said pilot signals, and a communication system comprising at least one network element.

BACKGROUND OF THE INVENTION

Wireless communication systems are widely deployed to provide various types of communication such as voice, packet data, and so on. These systems may be multiple-access systems capable of supporting communication with multiple users sequentially or simultaneously by sharing the available system resources. Examples of such systems include Code Division Multiple Access (CDMA) systems, Time Division Multiple Access (TDMA) systems, and Orthogonal Frequency Division Multiple Access (OFDMA) systems, or any combinations of these.

In wireless communication systems employing orthogonal frequency division multiplexing (OFDM), a transmitter transmits data to a receiver using many subcarriers in parallel. The frequencies of the sub-carriers are orthogonal. Transmitting the data in parallel allows the symbols containing the data to be of longer duration, which reduces the effects of multi-path fading. The orthogonality of the frequencies allows the sub-carriers to be tightly spaced, while minimizing inter-carrier interference. At the transmitter, the data is encoded, interleaved, and modulated to form data symbols. Each OFDM symbol is allocated to represent a component of a different orthogonal frequency. An inverse Fast Fourier Transform (IFFT) is applied to

the OFDM symbol to generate time samples of a signal. Cyclic extensions, in particular in form of a cyclic prefix (CP), are added to the signal, and the signal is passed through a digital-to-analog converter. Finally, the transmitter transmits the signal to the receiver along a channel

When the receiver receives the signal, the inverse operations are performed. The received signal is passed through an analog-to-digital converter, and timing information is then determined. The cyclic extensions are removed from the signal. The receiver performs a fast Fourier transformation (FFT) on the received signal to recover the frequency components of the signal, that is, the data symbols. Error correction may be applied to the data symbols to compensate for variations in phase and amplitude caused during propagation of the signal along the channel. The data symbols are then demodulated, de-interleaved, and decoded, to yield the transmitted data.

The variations in phase and amplitude resulting from propagation along the channel are referred to as the channel response. The channel response is usually frequency and time dependent. If the receiver can determine the channel response, the received signal can be corrected to compensate for the channel degradation. The determination of the channel response is called channel estimation. OFDM systems promise high data rates with low complexity due to the simplicity of the FFT and one-tap propagation channel. However, this can be assured only if the receiver is in a synchronization mode. A drawback of OFDM systems is that they are vulnerable to frequency errors.

An accurate estimate of the response of a wireless channel between a transmitter and a receiver is needed in order to effectively transmit data on the available subbands. Channel estimation is typically performed by sending a pilot from the transmitter and measuring the pilot at the receiver. Since the pilot is made up of symbols that are known a priori by the receiver, the channel response can be estimated as the relation of the received pilot symbols over the transmitted pilot symbols. This relation may include any channel dependent information as amplitude, phase, frequency shift, angular spread, interference, noise, etc. The receiver compares the

received value of the pilot symbols with the known transmitted value of the pilot symbols to estimate the channel response.

A pilot transmission represents an overhead in a wireless communication system. Thus, it is desirable to minimize pilot transmission to the extent possible. However, because of noise, fading, Doppler, interference, angular dispersion and other artifacts in the wireless channel, a sufficient amount of pilot energy needs to be transmitted frequently enough in order for the receiver to obtain a reasonably accurate estimate of the time-variant channel response. Because the contributions of physical scatters and the propagation paths to the channel response vary over time, the pilot transmission needs to be repeated regularly. The time duration over which the wireless channel may be assumed to be relatively constant is often referred to as a channel coherence time. The repeated pilot transmissions need to be spaced significantly closer in time than the channel coherence time to maintain high system performance. Similarly, for a wideband transmission, the pilot spacing in frequency also has to be sufficiently tight, to be able to estimate the full frequency dependent channel, which possibly extends over the coherence band. The coherence time of a channel may depend, for instance, on the velocity of the receiver. The coherence bandwidth of a channel may depend, for instance, on the delay spread of the channel.

In the downlink of a wireless communication system, a single pilot transmission from an access point (or a network element or a base station or a base station controller) may be used by a number of terminals to estimate the response of the distinct channels from the access point to each of the terminals. Furthermore, the pilot signals of different access points need to be separable form each other, from random data and from noise or interference to allow reliable estimation of the channel between the access point and the terminal. In the uplink, the channel from each of the terminals to the access point typically needs to be estimated through separate pilot transmissions from each of the terminals.

In the current IEEE 802.16m system, OFDMA is used in both uplink and downlink channels as the access technique. However, the single-carrier frequency division

multiple access (SC-FDMA) with cyclic prefix (CP) provides additional advantages. It is well known that, compared to OFDMA, one of the main benefits provided by single-carrier transmission is the significantly lower peak-to-average power ratio (PAPR) or cubic metric (CM). The reduction of PAPR or CM channel provides corresponding improvements in power-amplifier efficiency and coverage area. Another problem with OFDMA in mobile environment results from an inevitable frequency offset in the frequency references among different terminals. It has already been demonstrated that using SC-FDMA can overcome this disadvantage, too. Therefore, there is an approach to incorporate the SC-FDMA concept into the IEEE 802.16m system.

SUMMARY OF THE INVENTION

It is an object of the present invention to keep a similar or even lower overhead as that of a legacy system, when the SC-FDMA and IEEE 802.16m concepts are combined with each other.

It is a further object of the present invention to propose a pilot pattern structure which enables the SC-FDMA concept to work with the OFDMA concept in uplink substantially harmonically.

It is a still further object of the present invention to keep the advantage of a lower PAPR when the SC-FDMA concept works with the OFDMA concept.

In order to achieve the above and further objects, in accordance with a first aspect of the present invention, there is provided a method of providing pilot signals in OFDM frames, each OFDM frame comprising a predetermined plurality of OFDM symbols, in a telecommunication network, wherein at least one pilot signal is placed in addition to other data and/or signals within at least one existing OFDM symbol of said predetermined plurality of OFDM symbols.

Further advantageous embodiments and modifications of the method according to the first aspect of the present invention are defined in the dependent claims 2 to 23.

Moreover, preferably each OFDM frame is divided into a predetermined number of sub-frames, and each sub-frame includes a predetermined number of OFDM symbols. The number of sub-frames may be eight, and the number of OFDM symbols may be six.

In accordance with a second aspect of the present invention, there is provided a computer program embodied on a computer readable medium wherein the computer program is configured to perform the method according to the aforementioned first aspect.

In accordance with a third aspect of the present invention, there is provided a network element for a telecommunication network, comprising an OFDM generator configured to generate OFDM frames, each OFDM frame comprising a predetermined plurality of OFDM symbols, a pilot generator configured to generate pilot signals, and a transmitter configured to transmit said OFDM frames and said pilot signals, wherein said pilot generator is configured to place at least one pilot signal within at least one OFDM symbol of said predetermined plurality of OFDM symbols as generated by said OFDM generator, wherein said OFDM generator is configured to place other data and/or signals within the OFDM symbols, and said pilot generator is configured to place the at least one pilot signal in addition to the other data and/or signals within the at least one OFDM symbol.

Further advantageous embodiments and modifications of the network element according to the third aspect of the present invention are defined in the dependent claims 26 to 35.

Moreover, said pilot generator may be configured to place all pilot signals of a pilot pattern within one OFDM symbol.

Said OFDM generator may be configured to generate OFDM frames so that they have a time domain and a frequency domain and said OFDM symbols occur one after another in direction of said time domain, and said pilot generator is configured to place said pilot signals at a predetermined time in said time domain within at least a part of a region or within the whole region of the frequency domain. Further,

said pilot generator may be configured to scatter said pilot signals over the region of the frequency domain.

According to a further preferred embodiment, said pilot generator is configured to distribute said pilot signals essentially evenly over the region of the frequency domain.

According to a still further preferred embodiment, said pilot generator is configured to distribute said plurality of pilot signals essentially evenly over the region of the time domain. Said pilot generator may be configured to incorporate only one pilot signal or a block of frequency continuous pilot signals into each OFDM symbol. Further, said pilot generator may be configured to scatter said plurality of pilot signals over both the whole region of the time domain and the whole region of the frequency domain.

According to a still further preferred embodiment, said pilot generator is configured to scatter all pilot signals of a pattern over both the region of the time domain and the region of the frequency domain.

According to a still further preferred embodiment, said transmitter is configured to use the at least one pilot signal in an uplink channel of an IEEE 802.16m system when SC-FDMA and OFDMA systems are employed simultaneously.

Preferably, said OFDM generator is configured to generate OFDM frames so that each OFDM frame is divided into a predetermined number of sub-frames, and each sub-frame includes a predetermined number of OFDM symbols, wherein the number of sub-frames may be eight, and the number of OFDM symbols may be six.

Further, the network element may comprise a receiver configured to use said pilot signals for channel synchronization and/or channel estimation.

Preferably, said pilot generator is configured to perform the placement of the at least one pilot signal within the at least one OFDM symbol in an adaptive manner so as to reduce overhead.

In terms of the present invention, the network element is defined as being e.g. an access point, a base station, a base station controller or a user equipment.

In accordance with a fourth aspect of the present invention, there is provided a communication system comprising at least one network element according to the aforementioned third aspect.

For SC-FDMA, in order to keep the PAPR low, the best way would be to put the pilot and the data in different OFDM symbols, as is the case with the uplink design of the 3GPP LTE (third generation partnership project long term evaluation) system. If pilot and data are multiplexed into one OFDM symbol, obviously, the PAPR will increase significantly without any elegant design. However, according to the frame structure and pilot overhead requirements of the IEEE 802.16m standard, it is impossible to let pilots occupy one whole OFDM symbol. E.g., if an OFDM frame is divided into a predetermined number of sub-frames, each sub-frame includes 6 symbols, and one whole OFDM symbol is used to accommodate pilots only, the overhead will be 1/6, whereas the overhead for an adaptive modulation and coding (AMC) mode in a legacy system is 1/9. It is assumed that the overhead of the IEEE 802.16m system is required to be lower than that of the 802.16e system. So, one whole OFDM symbol cannot be used as the pilots for SC-FDMA in the IEEE 802.16m system.

In order to keep the same or lower overhead as that of the legacy system, according to the present invention pilot carrier and data carrier are put together into one OFDM symbol. Further, in order to still keep the advantage of a lower PAPR, new pilot pattern and new pilot sequence are proposed by this invention. In particular, in order to accommodate with the IEEE 802.16m frame structure and to keep the same pilot overhead as in the legacy system, the present invention proposes pilot patterns to enable the SC-FDMA concept to work with OFDMA in uplink harmonically.

According to exemplary embodiments, two exemplary kinds of pilot patterns are proposed. A first exemplary pilot pattern may be provided by inserting all the pilots

into the same OFDMA symbol. A second exemplary pilot pattern may be provided by scattering the pilots across the time-frequency region, in particular across the whole time-frequency region.

With the pilot patterns as proposed by the present invention data can be multiplexed with the pilot in one OFDM symbol, wherein even the PAPR can be reduced and therefore kept lower than in the prior art.

BRIEF DESCRIPTION OF THE DRAWINGS

Further embodiments, details, advantages and modifications of the present invention will become apparent from the following detailed description of the preferred embodiments which is to be taken in conjunction with the accompanying drawings, in which:

Figure 1 schematically shows a basic frame structure according to the IEEE 802.16m system description document;

Figure 2 schematically shows a pilot pattern proposed in the prior art for the LTE system;

Figure 3 schematically shows a pilot pattern according to a first exemplary embodiment in a first modification (a) and a second modification (b);

Figure 4 schematically shows a pilot pattern according to a second exemplary embodiment;

Figure 5 is a schematical diagram showing the value of cubit metric for QPSK with the roll-off factor being 0.15 in accordance with different scenarios; and

Figure 6 is a schematical diagram showing the value of cubit metric for 16 QAM with the roll-off factor being 0.15 in accordance with different scenarios.

DESCRIPTION OF THE PREFERRED EMBODIMENT

The IEEE 802.16m basic frame structure is assumed to be as schematically illustrated in Figure 1. Each 20 ms super-frame is divided into four equally-sized 5ms radio frames. When using the same OFDMA numerology as in the 802.16e system, each 5 ms radio frame further consists of eight sub-frames. Each sub-frame can be assigned for either downlink or uplink transmission depending on the duplexing scheme. There are two types of sub-frames: 1) the regular sub-frames which consist of six OFDMA symbols and 2) the irregular sub-frames that consist of five or less OFDMA symbols. The basic frame structure is applied to e.g. frequency division duplex (FDD), time division duplex (TDD), and half frequency division duplex (H-FDD) schemes. In each subframe, physical resource blocks (PRBs) are defined as the minimum resource allocation unit. One PRB is defined as e.g. consisting of N continuous carriers x M continuous OFDM symbols (i.e., N=18, M=6 for a regular sub-frame and N=18, M=5 for a non-regular sub-frame in current 802.16m system).

For SC-FDMA, in order to keep the PAPR low, the best way would be to put the pilot and the data in different OFDM symbols, as is the case with the uplink design of the 3GPP LTE system. If pilot and data are multiplexed into one OFDM symbol, obviously, the PAPR will increase significantly without any elegant design. However, according to the frame structure and pilot overhead requirements of the IEEE 802.16m standard, it is impossible to let pilots occupy one whole OFDM symbol. Specifically, as mentioned before with reference to Figure 1, in the IEEE 802.16m basic frame structure one OFDM frame is divided into eight sub-frames, and one sub-frame includes six symbols. If one whole OFDM symbol is used as pilots, i.e. to accommodate pilots only, as shown by example in Figure 2, the overhead will be 1/6, whereas the overhead for an adaptive modulation and coding (AMC) mode in a legacy system is 1/9. It is assumed that the overhead of the IEEE 802.16m system is required to be lower than that of the 802.16e system. So, one whole OFDM symbol cannot be used as the pilots for SC-FDMA in the IEEE 802.16m system.

In order to keep the same or lower overhead as that of the legacy system, according to the present invention pilot carrier and data carrier are put together into one OFDM symbol. Further, in order to still keep the advantage of a lower PAPR, new pilot pattern and new pilot sequence are proposed herein after with reference to exemplary embodiments. Moreover, in order to accommodate with the IEEE 802.16m frame structure and to keep the same or less pilot overhead than in the legacy system, pilot patterns are proposed to enable the SC-FDMA concept to work with OFDMA in uplink harmonically.

In the following, two kinds of pilot patterns are described as exemplary embodiments. In the first pilot pattern, all the pilots are inserted in the same OFDM symbol, which is shown in Figure 3. In the second pilot pattern, the pilots are scattered across the whole time-frequency region, which is shown in Figure 4. When the pilot overhead is relatively high, e.g. 1/9, the pilot pattern in Figure 3(a) is suggested to be used. Otherwise, when the pilot overhead is relatively low, e.g. 1/18, pilot patterns shown in Figure 3(b) and Figure 4 are recommended.

In the first pilot pattern as shown in Figure 3, under the assumption that the number of subcarriers is *N* and the amount of the pilot overhead is $P/Qx\frac{1}{6}$ (P is relatively prime to Q), a number of $Qm+p$ $(p=0,1,\cdots P-1)$ $(m=0,1,\cdots,(N/Q-1))$ subcarriers in the 4th OFDM symbol are allocated for pilots, and other subcarriers are for data. The symbols in the $(Qm+p)$th subcarrier is $s_u(mP+p)$, which is a Zadoff-Chu sequence and given by

$$s_u(k=mP+p)=\begin{cases}\exp\left\{-j2\pi\mu\dfrac{k(k+1)+qk}{2N_G}\right\}, for\ odd\ N_G\\ \exp\left\{-j2\pi\mu\dfrac{k^2+qk}{2N_G}\right\}, for\ even\ N_G\end{cases}$$

where N_G is an integer number being $k = 0, \cdots, N_G - 1$, q is an any integer, and $\mu = 1, \cdots, N_G - 1$. For simplicity, it can be chosen $q = 0, \mu = 1, N_G = N \times \frac{P}{Q}$.

In the pilot pattern shown in Figure 4, the pilot symbol can be chosen according to traditional OFDMA pilot design criteria.

With these pilot patterns, data can be multiplexed with the pilot in one OFDM symbol, but the PAPR can still be kept relatively low.

For a comparative simulation, each resource block (RB) is assumed to include 18 subcarriers and 6 OFDM symbols (18x6), and 1024 subcarriers are assumed to be included in each OFDM symbol. For SC-FDMA, all the pilots are inserted in one OFDM symbol, as shown in Figure 2. For OFDMA, pilots are inserted by an AMC mode according to the IEEE 802.16e standard. Since the number of RBs used in the uplink channel will impact on the CM performance, the CM performance is given with different RB numbers, i.e., RB number is 1, 2, 4, 8, 16 and 32.

When the overhead is 1/9, with the first pilot pattern as shown in Figure 3, the CM gain is at least 1.1 dB over OFDMA. When the overhead is 1/18, with the second pilot pattern as shown in Figure 4, the CM gain is about 1.2 dB for a quadrature phase shift keying (QPSK) case. For a 16 quadrature adaptive modulation (QAM) case, about 0.8 dB gain is still kept. The QPSK case is shown in Figure 5, and the QAM case is show in Figure 6.

It is to be understood that in the embodiment of the present invention, the operations are performed in the sequence and manner as shown although the order of some operations and the like may be changed without departing from the spirit and scope of the present invention.

The steps of the methods or algorithms described in connection with the embodiments disclosed herein may be embodied directly in hardware, in a software module executed by a processor, or in a combination of the two. A software module may reside in RAM memory, flash memory, ROM memory, EPROM memory,

EEPROM memory, registers, hard disk, a removable disk, a CD-ROM, or any other form of storage medium known in the art. An exemplary storage medium is coupled to the processor such that the processor can read information from, and write information to, the storage medium. In the alternative, the storage medium may be integral to the processor. The processor and the storage medium may reside in an ASIC. The ASIC may reside in a user terminal. In the alternative, the processor and the storage medium may reside as discrete components in a user terminal.

With respect to the present invention, network devices may be any device that utilizes network data, and can include switches, routers, bridges, gateways or servers. In addition, while the terms frame and signals have been used in the description of the present invention, the invention has import to many types of network data. For purposes of this invention, the term data includes packet, cell, frame, datagram, bridge protocol data unit packet, packet data and any equivalents thereof.

The many features and advantages of the invention are apparent from the detailed specification and, thus, it is intended by the appended claims to cover all such features and advantages of the invention which fall within the true spirit and scope of the invention. Further, since numerous modifications and changes will readily occur to those skilled in the art, it is not desired to limit the invention to the exact construction and operation illustrated and described, and accordingly all suitable modifications and equivalents may be resorted to, falling within the scope of the invention.

Claims

1. A method of providing pilot signals in OFDM (orthogonal frequency division multiplexing) frames, each OFDM frame comprising a predetermined plurality of OFDM symbols, in a telecommunication network,
wherein at least one pilot signal is placed in addition to other data and/or signals within at least one existing OFDM symbol of said predetermined plurality of OFDM symbols.

2. The method according to claim 1, wherein at least one pilot signal is multiplexed with the data within the at least one OFDM symbol.

3. The method according to claim 2, wherein the at least one pilot signal is interleaved with the data.

4. The method according to claim 3, wherein the at least one pilot signal is essentially periodically interleaved with the data.

5. The method according to claim 3 or 4, wherein the at least one pilot signal is interleaved with the data in one resource block including a plurality of OFDM symbols.

6. The method according to at least any one of the preceding claims, wherein at least one data carrier carrying data and at least one pilot carrier carrying the at least one pilot signal are inserted in the at least one OFDM symbol.

7. The method according to at least any one of the preceding claims, wherein a predetermined plurality of pilot signals define a pilot pattern.

8. The method according to at least any one of the preceding claims, wherein a predetermined plurality of pilot signals define a pilot sequence.

9. The method according to claim 8, wherein said pilot sequence is a Zadoff-Chu sequence.

10. The method according to at least any one of the preceding claims, wherein a predetermined plurality of pilot signals are placed within one OFDM symbol.

11. The method according to claims 7 and 10, wherein all pilot signals of a pilot pattern are placed within one OFDM symbol.

12. The method according to claim 10 or 11, each OFDM frame having a time domain and a frequency domain, wherein said OFDM symbols occur one after another in direction of said time domain, and said pilot signals are placed at a predetermined time in said time domain within at least a part of a region in direction of the frequency domain.

13. The method according to claim 12, wherein said pilot signals are placed within the whole region of the frequency domain.

14. The method according to claim 12 or 13, wherein said pilot signals are scattered over the region of the frequency domain.

15. The method according to at least any one of claims 12 to 14, wherein said pilot signals are distributed essentially evenly over the region of the frequency domain.

16. The method according to at least any one the claims 1 to 9, each OFDM frame having a time domain and a frequency domain, wherein a predetermined plurality of pilot signals are scattered over both at least a part of a region of the time domain as well as at least a part of a region of the frequency domain.

17. The method according to claim 16, wherein said plurality of pilot signals are distributed essentially evenly over the region of the time domain.

18. The method according to claim 16 or 17, wherein each OFDM symbol in one resource block includes only one pilot signal or a block of frequency continuous pilot signals.

19. The method according to at least any one of the claims 16 to 18, wherein said plurality of pilot signals are scattered over both the whole region of the time domain and the whole region of the frequency domain.

20. The method according to claim 7 as well as according to at least any one of the claims 16 to 19, wherein all pilot signals of a pattern are scattered over both the region of the time domain and the region of the frequency domain.

21. The method according to at least any one of the preceding claims, wherein the at least one pilot signal is used in an uplink channel when only SC-FDMA (single-carrier frequency division multiple access) are employed or SC-FDMA and OFDMA (OFDM access) systems are employed simultaneously.

22. The method according to at least any one of the preceding claims, wherein said pilot signals are used for channel synchronization and/or channel estimation.

23. The method according to at least any one of the preceding claims, wherein the placement of the at least one pilot signal within the at least one OFDM symbol is carried out in an adaptive manner so as to reduce overhead.

24. A computer program embodied on a computer readable medium, the computer program being configured to perform the method according to at least any one of the preceding claims.

25. A network element for a telecommunication network, comprising
an OFDM generator configured to generate OFDM frames, each OFDM frame comprising a predetermined plurality of OFDM symbols,
a pilot generator configured to generate pilot signals, and
a transmitter configured to transmit said OFDM frames and said pilot signals,
wherein said pilot generator is configured to place at least one pilot signal within at least one OFDM symbol of said predetermined plurality of OFDM symbols as generated by said OFDM generator, wherein said OFDM generator is configured to place other data and/or signals within the OFDM symbols,

and said pilot generator is configured to place the at least one pilot signal in addition to the other data and/or signals within the at least one OFDM symbol.

26. The network element according to claim 25, wherein said pilot generator comprises a multiplexer configured to multiplex the at least one pilot signal with the data within the at least one OFDM symbol.

27. The network element according to claim 25 or 26, wherein said pilot generator comprises an interleaver configured to interleave the at least one pilot signal with the data.

28. The network element according to claim 27, wherein said interleaver is configured to essentially periodically interleave the at least one pilot signal with the data.

29. The network element according to claim 27 or 28, wherein said interleaver is configured to interleave the at least one pilot signal with the data in one resource block including a plurality of OFDM symbols.

30. The network element according to at least any one of claims 25 to 29, wherein said OFDM generator is configured to insert at least one data carrier carrying data in the at least one OFDM symbol, and said pilot generator is configured to insert at least one pilot carrier carrying the at least one pilot signal in the at least one OFDM symbol.

31. The network element according to at least any one of the claims 25 to 30, wherein said pilot generator is configured to generate a pilot pattern including a predetermined plurality of pilot signals.

32. The network element according to at least any one of the claims 25 to 31, wherein said pilot generator comprises a sequencer configured to define a predetermined plurality of pilot signals as a pilot sequence.

33. The network element according to claim 32, wherein said sequencer is configured to define said pilot sequence as a Zadoff-Chu sequence.

34. The network element according to at least any one of the claims 25 to 33, wherein said pilot generator is configured to place a predetermined plurality of pilot signals within one OFDM symbol.

35. The network element according to at least any one of the claims 25 to 33, wherein said OFDM generator is configured to generate OFDM frames so that they have a time domain and a frequency domain, and said pilot generator is configured to scatter a predetermined plurality of pilot signals over both at least a part of a region of the time domain as well as at least a part of a region of the frequency domain.

36. The network element according to at least any one of the claims 25 to 35, wherein said network element is an access point, a base station, a base station controller or a user equipment.

37. A communication system, comprising at least one network element according to at least any one of the claims 25 to 36.

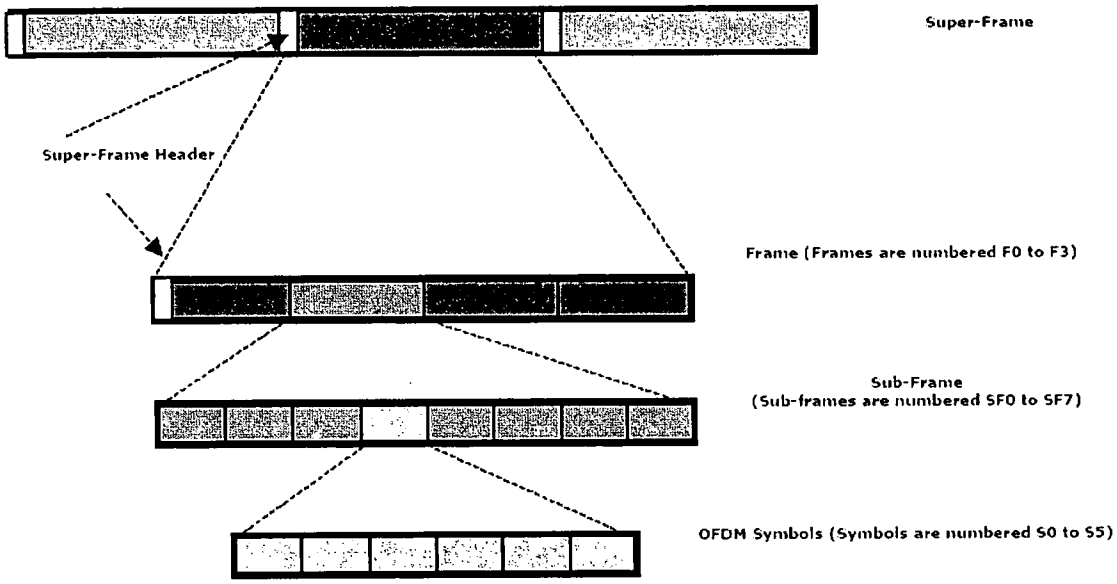

Super-Frame
Super-Frame Header
Frame (Frames are numbered F0 to F3)
Sub-Frame
(Sub-frames are numbered SF0 to SF7)
OFDM Symbols (Symbols are numbered S0 to S5)

Figure 1

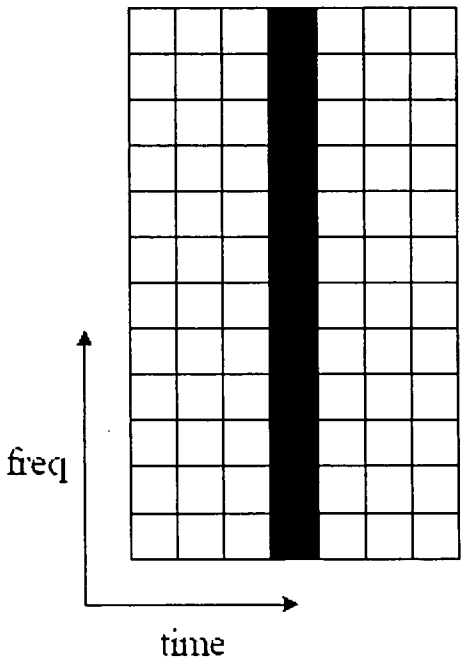


Figure 2

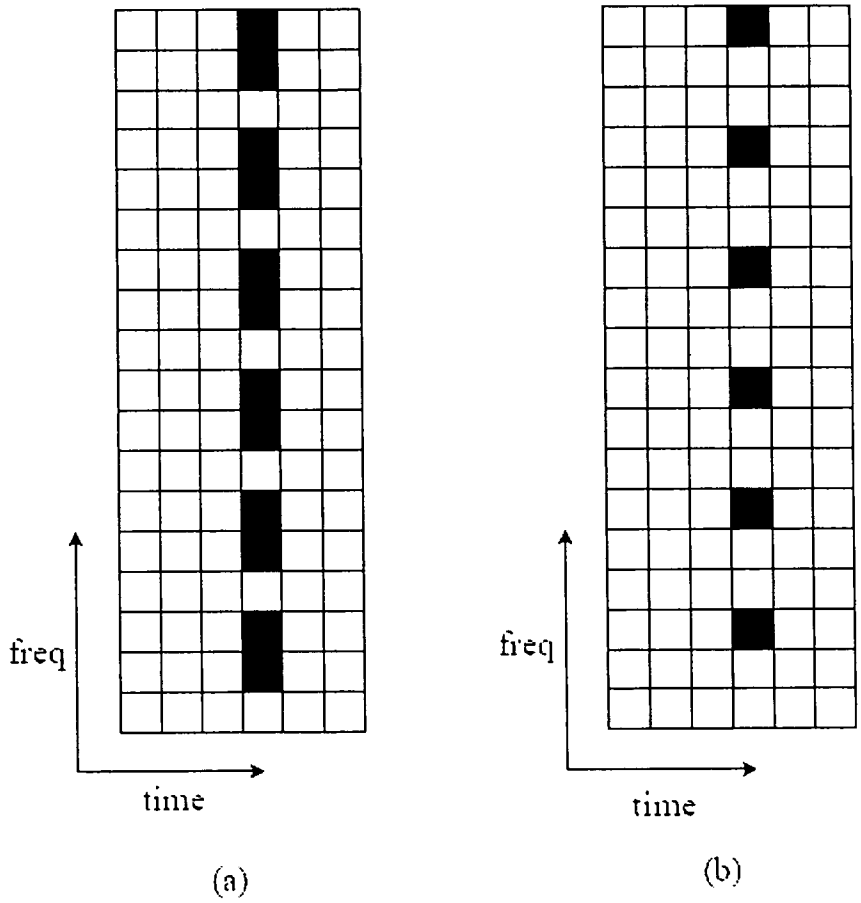


Figure 3

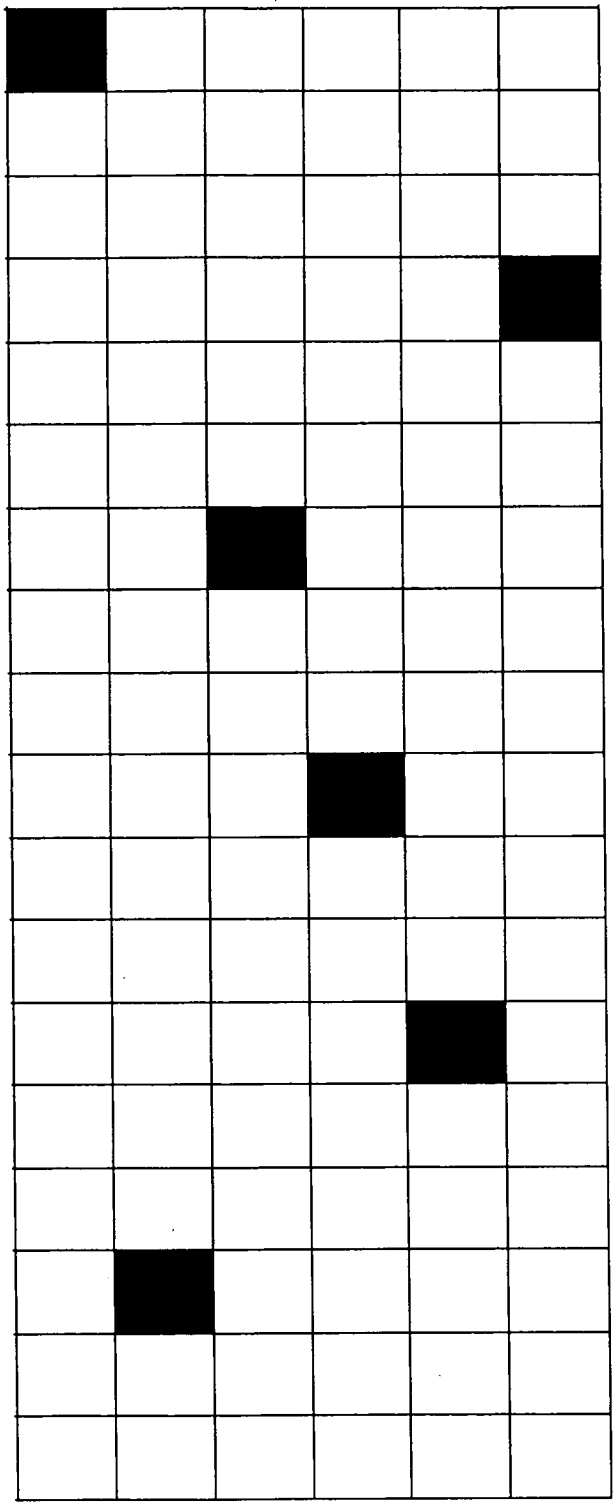
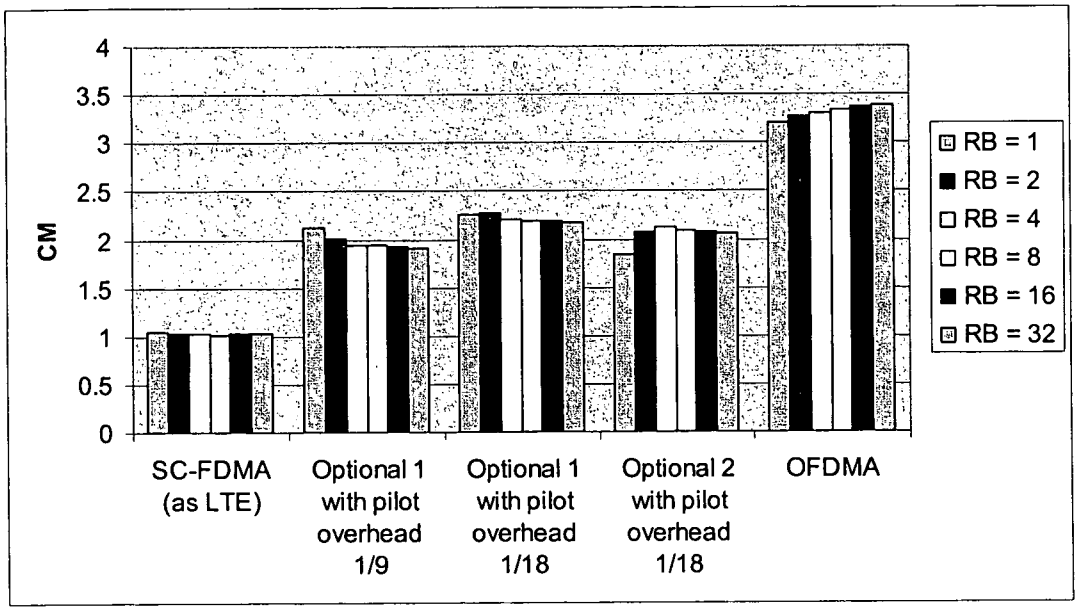


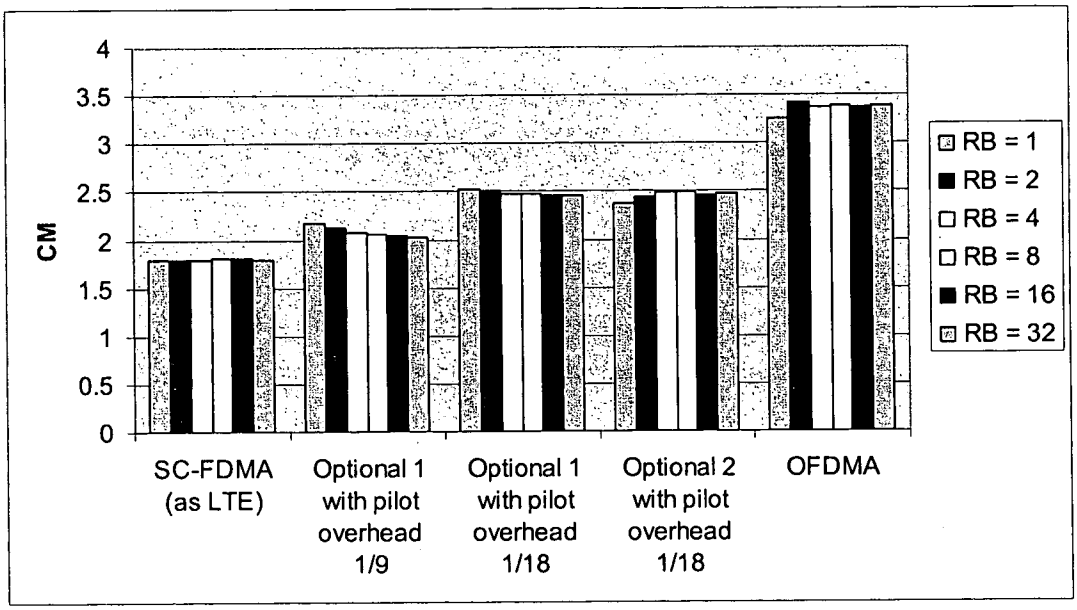
Figure 4



Cubic metric for QPSK with roll-off factor 0.15

	RB = 1	RB = 2	RB = 4	RB = 8	RB = 16	RB = 32
SC-FDMA (as LTE)	1.0382	1.033	1.0278	1.0206	1.0289	1.0285
Optional 1 with pilot overhead 1/9	2.1255	2.0028	1.9447	1.9362	1.9179	1.9072
Optional 1 with pilot overhead 1/18	2.2598	2.2723	2.1998	2.1869	2.1887	2.1807
Optional 2 with pilot overhead 1/18	1.8367	2.0757	2.1196	2.0882	2.0686	2.0601
OFDMA	3.2052	3.2714	3.3083	3.3287	3.3658	3.3901

Figure 5



Cubic metric for 16 QAM with roll-off factor 0.15

	RB = 1	RB = 2	RB = 4	RB = 8	RB = 16	RB = 32
SC-FDMA (as LTE)	1.7932	1.7983	1.7932	1.8089	1.8069	1.7954
Optional 1 with pilot overhead 1/9	2.1719	2.1224	2.0799	2.0597	2.0428	2.0209
Optional 1 with pilot overhead 1/18	2.5297	2.5074	2.4735	2.4772	2.4576	2.4526
Optional 2 with pilot overhead 1/18	2.369	2.4406	2.4941	2.4921	2.4622	2.4761
OFDMA	3.2506	3.422	3.3765	3.3799	3.373	3.3865

Figure 6

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2008/004239

A. CLASSIFICATION OF SUBJECT MATTER
INV. H04L27/26

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
H04L

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2007/217531 A1 (KWON YEONG HYEON [KR] ET AL) 20 September 2007 (2007-09-20) abstract; figures 1,2,5-8,12-16 paragraph [0010] - paragraph [0013] paragraph [0074] - paragraph [0079] paragraph [0085] - paragraph [0122] paragraph [0142] - paragraph [0143] paragraph [0154] - paragraph [0155] paragraph [0158] - paragraph [0160]	1-37

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[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
6 May 2009	15/05/2009

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Haas, Hans

Form PCT/ISA/210 (second sheet) (April 2005)

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2008/004239

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

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X	FERNÀNDEZ-GETINO GARCÍA M J ET AL: "Pilot patterns for channel estimation in OFDM" ELECTRONICS LETTERS, IEE STEVENAGE, GB, vol. 36, no. 12, 8 June 2000 (2000-06-08), pages 1049-1050, XP006015292 ISSN: 0013-5194 figure 1 page 1, column 1, line 1 - column 2, line 21	1-37
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X	EP 1 650 921 A (IND TECH RES INST [TW]) 26 April 2006 (2006-04-26) claim 1; figure 1 paragraph [0003] - paragraph [0005]	1-37

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Information on patent family members

International application No
PCT/EP2008/004239

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