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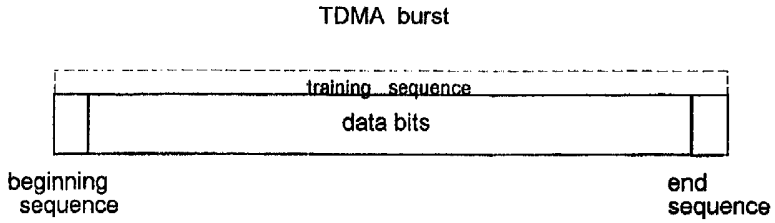
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(54) Title: METHOD, TRANSMITTER AND RECEIVER FOR TRANSMITTING TRAINING SIGNALS IN A TDMA TRANSMISSION SYSTEM



(57) Abstract

The invention relates to a TDMA method, transmitter and receiver, wherein a training sequence is modulated and superposed on a data signal to thereby generate a TDMA burst. Thereby, the training sequence can be made longer and is always available during data reception, such that longer channel impulse responses can be measured. In the transmitter, the training sequence is separately modulated in a modulating means (3) before being superposed on the data signal. The receiver comprises an extracting means (11) for extracting the superposed training sequence and a cancelling means (9) for cancelling the training sequence from the data signal to be detected.

METHOD, TRANSMITTER AND RECEIVER FOR TRANSMITTING TRAINING SIGNALS IN A TDMA TRANSMISSION SYSTEM

The invention relates to a TDMA (Time Division Multiple Access) method, transmitter and receiver. In particular, the present invention relates to a digital mobile communication system, such as the GSM system (Groupe Spécial Mobile) or the DCS (Digital Cellular System).

BACKGROUND OF THE INVENTION

In the TDMA class of digital mobile communication systems, several users share one carrier. Each user is allocated a separate time slot on that carrier, which is used to transmit and receive short bursts of data packets separated by a guard time. The number of users on one carrier is limited to the number of slots allocated to that particular carrier.

The GSM system is described e.g. in "The GSM System for Mobile Communications", M. Moyly and M.-B. Pautet, Palaiseau, France, 1992, ISBN: 2-9507190-0-7 and is therefore not described herein in geater detail.

In current GSM systems, as for example described in document WO-A-95/28771, a predetermined bit sequence in the middle of the data in a TDMA burst is used as a training sequence required in order to calculate parameters of an impulse response of a respective channel, i.e. estimated channel impulse response taps. These parameters are used for removing interactions caused by multipath transmission.

Currently, approximately five taps of the channel impulse response can be measured by the available training sequences. If longer impulse responses should be measured, a longer training sequence would be required which would decrease the amount of data within the TDMA burst.

Regarding the problem of reduced transmission efficiency associated with the use of longer training sequences, document EP-A-0 355 587 suggests to delete training preambles

within a TDMA burst and, instead, to store baseband quadrature signal components as sampled data of an entire slot in delay buffers while the clock and carrier phases are estimated. However, in this case, complex signal processing circuits are necessary for obtaining the required estimations.

SUMMARY OF THE INVENTION

It would be desirable to provide a TDMA method, transmitter and receiver, by means of which longer impulse responses can be measured.

One aspect of the present invention provides a TDMA method, comprising the steps of modulating a training sequence and generating a TDMA burst by superposing the modulated training sequence upon a modulated data signal.

Another aspect of the present invention provides a transmitter for a TDMA system, comprising modulating means for modulating a training sequence, superposing means for generating a TDMA burst by superposing the modulated training sequence upon a modulated data signal, and transmitting means for transmitting said TDMA burst.

A further aspect of the invention provides a receiver for a TDMA system, comprising receiving means for receiving a TDMA burst, extracting means for extracting a superposed training sequence from the received TDMA burst, and cancelling means for cancelling the superposed training sequence before data detection.

Since the training sequence is superposed on the TDMA burst, a long training sequence which may be as long as the whole burst may be used. Thus, the training sequence is always available and can be used to measure longer or shorter channel impulse responses.

Another advantage is that this type of training sequence could be used for estimation of frequency error as well as any change in the channel impulse response over the burst.

A preferred embodiment of the method, transmitter and receiver of the invention is evident from the attached dependent claims.

BRIEF DESCRIPTION OF THE DRAWINGS

In the following, the invention and a preferred embodiment will be described in greater detail with reference to the accompanying drawings in which:

Fig. 1 shows a TDMA burst according to the prior art,

Fig. 2 shows a TDMA burst according to the present invention, and

Fig. 3 is a block diagram showing a transmitter and a receiver of a TDMA system according to an embodiment of the present invention.

As shown in Fig. 1, a known TDMA burst according to the GSM specifications contains two information sections (58 bits) separated by a training sequence (26 bits) in the middle of the burst. In addition the burst contains a short (3 bits) beginning and end sequence at the ends of the burst.

Fig. 2 shows a TDMA burst according to the present invention, wherein a longer training sequence is provided, which is not in the middle of the data but on top of (or better below) the data and which has less power. This is especially suitable for systems with large bursts, because in this case the training sequence can be long enough and therefore can be transmitted with less power. The beginning and end sequence may remain in the new structure.

As training sequences, those used in the GSM system or longer CAZAC sequences, e.g. those proposed in "Almost perfect autocorrelation sequences" by Jacques Wolfmann, IEEE Transactions on Information Theory, Vol. 38, No. 4, July 1992, or M-sequences may be used. The sequence is modulated and superposed, e.g. added, upon the data signal. If the sequence is not long enough, it may be repeated periodically. In this case, good periodical autocorrelation properties are required. The period should be long enough to ensure measurement of the required amount of taps of the channel inpulse response. If the period of the training sequence is 32 bits, then up to 15 taps can be measured, which is enough for most applications.

Since the total training sequence can be longer according to the present invention, the whole sequence can be repeated many times. Thereby, the whole training sequence or only a part of it can be used for channel estimation.

On the other hand, the period should not be too long, so that the training sequence can be used for estimating frequency errors, i.e. the channel impulse response can be measured in several points along the burst in order to derive phase changes as well as other changes.

The power of the superposed training sequence has to be small enough to prevent excessive disturbance of the modulated TDMA data signal. However, the power should be high enough to obtain reliable channel estimations. The power also depends on the length of the burst. In practice, the training sequence power should be 0 to 10 dB below the signal power.

Fig. 3 shows a block diagram comprising those parts of a transmitter unit and a receiver unit of an embodiment of the present invention, which are essential for understanding the present invention.

According to the upper portion of Fig. 3, the transmitter unit comprises a burst generating means 1 which generates a

burst on the basis of input data supplied thereto. The generated burst is modulated in a first modulating means. In addition thereto, a second modulating means 3 is provided for separately modulating a supplied training sequence. The modulated training sequence is attenuated in an attenuator 4 which, for example, may be adjustable. The attenuation factor of the attenuator 4 is selected so as to minimize disturbance of the data burst and to ensure reliable data detection. The attenuated modulated training sequence is superposed onto the modulated data burst. This can be effected by adding both modulated signals, for example.

In case Gaussian Minimum Shift Keying (GMSK) is used as a modulation method for transmission, the superposition of the data burst and the training sequence is preferably performed at intermediate frequency level.

In case a linear modulation is used in the TDMA system, the superposition of the data burst and the training sequence may also be performed at baseband level.

The modulation methods of the training sequence and the data burst may also differ from each other, as long as subsequent separation is possible without excessive deterioration. In order to be able to measure the whole channel, it is preferred to use same modulation frequencies for the above modulations of the data burst and the training sequence.

The resultant combined signal is filtered by a filtering means 5 in order to restrict the transmission bandwidth according to the corresponding system requirements. The combined and filtered TDMA signal obtained from the filtering means 5 is then supplied to a radio frequency (RF) transmitting means 6 which transmits the combined signal as an RF burst using a transmitting antenna.

The receiver unit shown in the lower part of Fig. 3 comprises an RF receiving means 7 which receives an RF burst with a receiving antenna. The RF receiving means 7 demodulates the

received RF burst by using a local oscillator (not shown). The demodulated TDMA signal is filtered by a filtering means 8 in order to remove unwanted frequency components. The received combined TDMA signal is branched and the superposed training sequence is extracted and detected by a channel estimating means 11 using a filtering means (not shown) such as an adapted filter.

The kind of extraction depends on the autocorrelation properties of the training sequence. If the training sequence exhibits good autocorrelation properties, then simple matched filter/correlation methods can be employed, i.e. the signal is correlated in the receiver with the known training sequence. Due to the good autocorrelation properties, the output of this correlation is the channel estimate plus noise generated due to the random data signal, interferences from other users and Gaussian noise. The training sequence could be any random sequence, but then more complex estimation methods would be required. Therefore, good sequences are preferrred.

The detected training sequence is used by said channel estimation means 11 to measure desired parameters of the channel impulse response.

In the other branch, the training sequence is cancelled from the received data burst by a training sequence cancelling means 11. The cancellation may be effected by an interference cancellation technique on the basis of the measured channel impulse response parameters which are supplied to the training sequence cancelling means 11 by the above mentioned channel estimating means 11. In the training sequence cancelling means 11, the training sequence can be regenerated and subtracted from the received signal before data detection.

Alternatively, the training sequence cancellation may be effected by simple cut-off or limiting techniques in case of

constant envelope data modulation. Thereby, any disturbance of subsequent data detection can be prevented.

After the superposed training sequence has been cancelled from the received burst, data detection is performed in a detector 10 on the basis of the channel impulse response parameters which are also supplied to the detector 10 from the channel estimating means 11. Finally, the detector 10 outputs the received data. Conventional detectors such as MLSE-detectors (Viterbi), DFE-detectors, etc. may be used as the detector 10.

The present invention could be further improved by providing a receiver in which iterations are employed. Therein, the channel estimation and the data detection are initially performed, followed by an estimation of the received data, which can be used to regenerate the received data signal, i.e. the detected bits are modulated and filtered with the channel estimate. The regenerated data signal can be subtracted from the received signal and a new channel estimation can be performed. In case most of the data bits are correct, this process improves the channel estimate. this leads to an improved training sequence cancellation and data detection. The iteration process can be repeated several times until a desired improvement has been reached.

For measuring frequency errors, separate channel estimates are performed at different parts of the data burst by using only a part of the training sequence. Subsequently, the phase errors between the channel estimates are measured and used as an indicator of frequency errors.

It should be understood that the above description and accompanying figures are only intended to illustrate the present invention. Thus, the method according to the invention may also be used in systems other than the described GSM system. The preferred embodiment of the method, receiver and transmitter of the invention may thus vary within the scope of the attached claims.

The claims defining the invention are as follows:

1. A TDMA method, comprising the steps of:
modulating a training sequence; and
generating a TDMA burst by superposing said modulated training sequence upon a modulated data signal.

2. A TDMA method according to claim 1,
wherein said training sequence is used for calculating parameters of an impulse response of a transmission channel.

3. A TDMA method according to claims 1 or 2,
wherein said method is used in a GSM or a DCS system.

4. A TDMA method according to either claim 2 or claim 3 when dependant upon claim 2,
wherein said training sequence is used for estimating a change in the channel impulse response over the TDMA burst and/or a frequency error.

5. A TDMA method according to any one of the preceding claims,
wherein said training sequence is a CAZAC sequence or an M sequence.

6. A TDMA method according to any one of the preceding claims,
wherein said modulated training sequence is added to a modulated data signal in order to generate said TDMA burst.

7. A TDMA method according to claim 6,
wherein the power of said superposed training sequence is smaller than the power of said modulated data signal.

8. A TDMA method according to any one of the preceding claims,

wherein said training sequence is repeated periodically within the length of said TDMA burst.

9. A TDMA method according to any one of the preceding claims,
wherein the power of said superposed training sequence is smaller than the power of said data signal.

10. A transmitter for a TDMA system, comprising:
modulating means for modulating a training sequence;
superposing means for generating a TDMA burst by superposing said modulated training sequence upon a modulated data signal; and
transmitting means for transmitting said TDMA burst.

11. A transmitter according to claim 10,
wherein said training sequence is modulated separate from said data signal in said modulating means.

12. A transmitter according to claim 10 or 11, comprising another modulating means for modulating said data signal.

13. A transmitter according to any one of claims 10 to 12,
comprising an attenuator for attenuating said modulated training sequence supplied from said modulating means before being superposed on said data signal.

14. A transmitter according to claim 13,
wherein said attenuator is adjustable.

15. A receiver for a TDMA system, comprising:
receiving means receiving a TDMA burst;
extracting means for extracting a training sequence superposed on the received TDMA burst; and
cancelling means for cancelling the superposed training sequence before data detection.

16. A receiver according to claim 15, wherein said extracting means comprises a filtering means for extracting said training sequence.

17. A receiver according to claim 16, wherein said filtering means is an adaptive filter.

18. A receiver according to any one of claims 15 to 17, wherein said extracting means is adapted to measure parameters of a channel impulse response on the basis of said extracted training sequence.

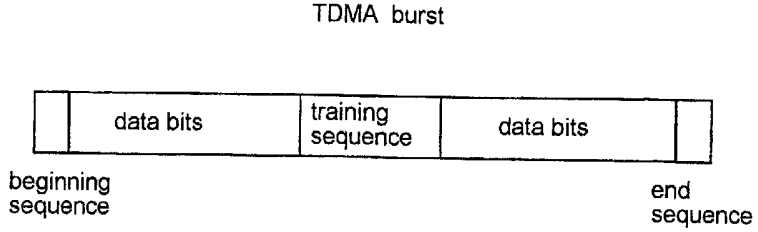
19. A receiver according to claim 18, wherein said parameters of said channel impulse response are supplied to said cancelling means which is adapted to cancel said training sequence from said received TDMA burst by means of an interference cancellation technique based on said supplied parameters.

20. A receiver according to claims 18 or 19, comprising a detector for performing data detection on the basis of said channel impulse response parameters which are supplied thereto.

21. A TDMA method substantially as hereinbefore described with reference to the accompanying drawings.

22. A transmitter for a TDMA system substantially as hereinbefore described with reference to the accompanying drawings.

23. A receiver for a TDMA system substantially as hereinbefore described with reference to the accompanying drawings.



PRIOR ART

Fig. 1

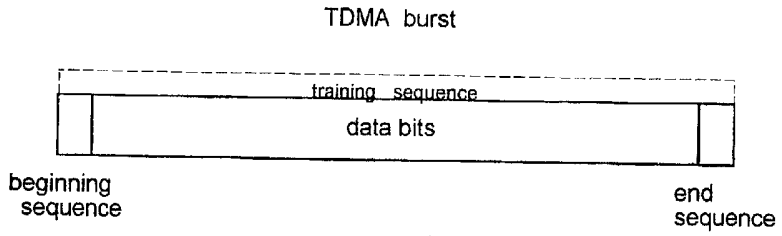


Fig. 2

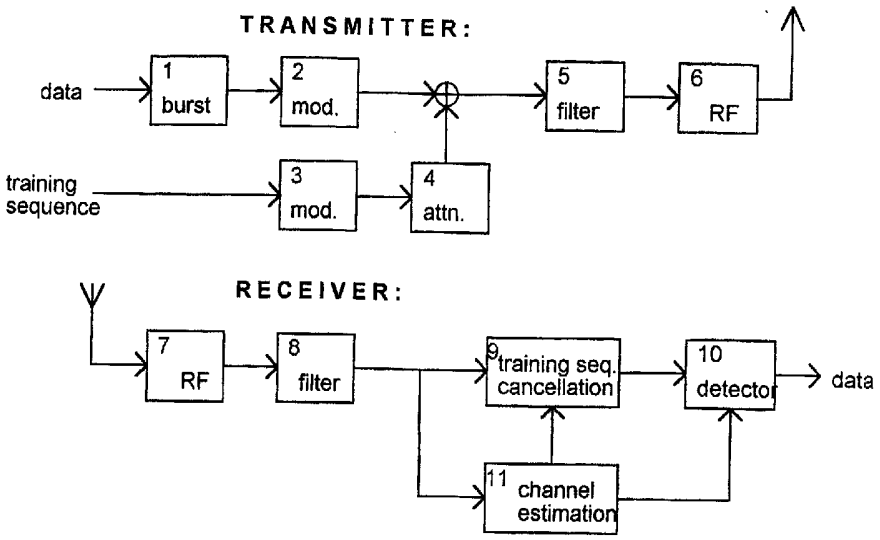

TRANSMITTER:
data
1
burst
2
mod.
5
filter
6
RF
training
sequence
3
mod.
4
attn.
RECEIVER:
7
RF
8
filter
9
training seq.
cancellation
10
detector
data
11
channel
estimation

Fig. 3