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(71) Applicant *(for all designated States except US)*: **SAMSUNG ELECTRONICS CO., LTD.** [KR/KR]; 416, Maetan-dong, Yeongtong-gu, Suwon-si, Gyeonggi-do 443-742 (KR).

(72) Inventors; and
(75) Inventors/Applicants *(for US only)*: **ZHOU, Lei** [CN/CN]; Beijing Samsung Telecom R&D Center, 12/F Zhongdian Fazhan Building, No.9, Xiaguangli, Chaoyang District, Beijing 100125 (CN). **ZHAO, Zheng** [CN/CN]; Beijing Samsung Telecom R&D Center, 12/F Zhongdian Fazhan Building, No.9, Xiaguangli, Chaoyang District, Beijing 100125 (CN). **LIANG, Zongchuang** [CN/CN]; Beijing Samsung Telecom R&D Center, 12/F Zhongdian Fazhan Building, No.9, Xiaguangli, Chaoyang District, Beijing 100125 (CN).

(74) Agents: **KWON, Hyuk-Rok** et al.; 2F. Seokwang Bldg., 1-96 Sinmun-ro 2ga, Jongro-ku, Seoul, 110-062 (KR).

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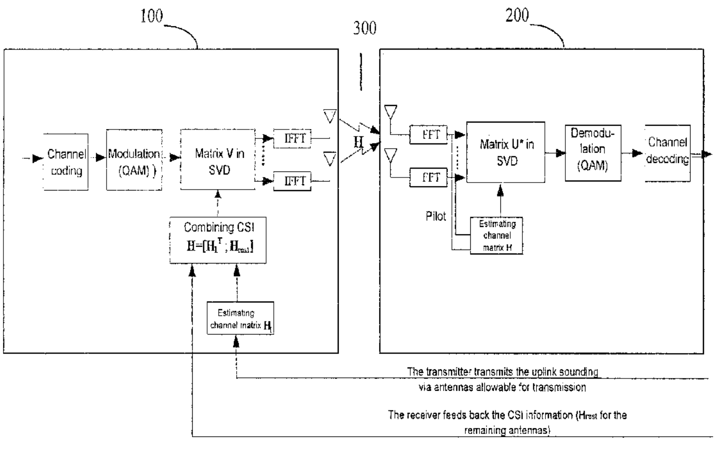
(54) **Title**: PRE-CODING METHOD AND APPARATUS BASED ON UPLINK SOUNDING AND CSI FEEDBACK CHANNEL INFORMATION

Fig. 2



(57) **Abstract**: A signal communication method for a TDD communication system is provided, comprising steps of: at a transmitter, coding and modulating information bits, multiplying the resulting signal with a pre-coding matrix V and allocating them to OFDM sub-carriers for transmitting via antennas allowable for transmission, wherein the pre-coding matrix V is obtained based on an uplink sounding signal and CSI channel feedback information for the remaining antennas from a receiver; and at the receiver, processing the received signal, estimating a channel matrix H based on a pilot, performing pre-decoding and demodulating based on the estimated matrix H and outputting the resulting information bits. According to the present invention, the problem that the transmitter can not obtain CSI for all transmitting antennas within one frame due to the difference of antenna configurations between the uplink and the downlink in a MIMO system. Meanwhile, the system performance can be improved and the feedback overhead and the complexity of the receiver can be reduced.

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Description

PRE-CODING METHOD AND APPARATUS BASED ON UPLINK SOUNDING AND CSI FEEDBACK CHANNEL INFORMATION

Technical Field

[1] The present invention relates to wireless mobile communication technology, in particular to a pre-coding method and apparatus based on uplink sounding and CSI feedback channel information.

Background Art

[2] Recently, there is an increasing demand on higher network capacity and better performance as wireless services become more and more important. However, only limited potential for improving spectral efficiency can be provided by such options as a wider bandwidth, an optimized modulation scheme and even a code multiplexing system.

[3] In a Multiple Input Multiple Output (MIMO) system, a space multiplexing technology can be employed to improve the bandwidth utilization by using antenna arrays. In many practices, channel parameters can be obtained from the feedback channel from the receiver to the transmitter on the assumption that the feedback delay is much shorter than the channel coherence time. Additionally, in a time division duplex (TDD) system, estimation values of the channel in the receiving mode can be used in the transmitting mode when the data receiving and transmitting are completed within a ping-pong period, assuming that the ping-pong period is much shorter than the channel coherence time. Therefore, the problem is: how to utilize these channel estimation values to optimize the transmitting scheme for the transmitter and to design the optimal receiver accordingly.

[4] The state-of-art researches can be mainly classified into the linearly and nonlinearly optimized pre-coding technologies. While the nonlinear pre-coding solution has better performance, the linear pre-coding technology is of most interest in research since the nonlinear one suffers from a much higher complexity. The linear pre-coding technology makes full use of all or parts of the Channel State Information (CSI) to obtain as much beam-forming gain as possible. The most common method applied in the linear pre-coding is the Singular Value Decomposition (SVD). Theoretically, the transmission rate of the SVD-based linear pre-coding technology can reach the channel capacity. In the SVD-based linear pre-coding technology, it is necessary for the transmitter to know as much CSI as possible.

[5] The fundamental principle of the SVD-based linear pre-coding technology is given

below.

[6] A MIMO system with N_t transmitting antennas and N_r receiving antennas in the case of a flat fading channel is considered. A received code element vector in the receiver can be expressed as:

[7] MathFigure 1

[Math.1]

$$\mathbf{y} = \mathbf{H}\mathbf{x} + \mathbf{n} \qquad (1)$$

[8] where x denotes a complex vector of a data code element, H denotes a $N_r \times N_t$ channel matrix conforming to the Rayleigh distribution, and n denotes an Additive White Gaussian Noise (AWGN) vector.

[9] The channel matrix H can be decomposed into three matrices with the SVD method, i.e., SVD{H} ={U,Σ,V}, where U and V are both unitary matrices and Σ is a diagonal matrix whose elements represent the singular values of the channel matrix H in descending order. The SVD expression of the channel matrix H is given by:

[10] MathFigure 2

[Math.2]

$$\mathbf{H} = \mathbf{U}\boldsymbol{\Sigma}\mathbf{V}^* \qquad (2)$$

[11] The block diagram of a SVD-based MIMO system is illustrated in Fig. 1. It can be seen in Fig.1 that the data code element vector x at the transmitter is multiplied with a pre-coding matrix V before being transmitted via N_t antennas. The data signal is transmitted via a MIMO channel to the receiver which receives the signal using N_r antennas and eliminates the channel impact with a pre-decoding matrix U*. The received vector y can be expressed as:

[12] MathFigure 3

[Math.3]

$$\begin{aligned} \mathbf{y} &= \mathbf{U}^*\mathbf{H}\mathbf{V}\mathbf{x} + \mathbf{U}^*\mathbf{n} \\ &= \mathbf{U}^*\mathbf{U}\boldsymbol{\Sigma}\mathbf{V}^*\mathbf{V}\mathbf{x} + \mathbf{U}^*\mathbf{n} \\ &= \boldsymbol{\Sigma}\mathbf{x} + \mathbf{U}^*\mathbf{n} \qquad (3) \end{aligned}$$

[13] In a MIMO system, in order to perform the SVD-based pre-coding process, two approaches can be used by the transmitter to obtain the pre-coding matrix V. On the one hand, the transmitter can obtain the pre-coding matrix V by applying the SVD to the channel matrix H which is derived from an uplink sounding signal transmitted by the

receiver. On the other hand, the transmitter can obtain the information on the pre-coding matrix V from the CSI fed back by the receiver.

[14] If the communication system operates in the FDD mode, only the second approach, i.e., obtaining the information on the pre-coding matrix V based on the feedback from the receiver, can be employed since the uplink and the downlink use different frequency bands, respectively. In the TDD mode, however, both approaches are applicable. In the TDD mode, if the transmitter can accurately obtain the pre-coding matrix V, the system performance can be improved and the complexity of the receiver can be reduced.

[15] In the TDD mode, there may be quantization errors and more feedback overhead for the CSI fed back according to the second approach. Therefore, it is desired in the TDD mode that the MIMO system can employ the first approach by which the channel matrix H is derived from the uplink sounding signal. However, in future MIMO systems, the number of antennas at the transmitter can be greater than that at the receiver, resulting in a mismatch of antenna configurations between the uplink and the downlink. Thus, there is a problem to be solved that the transmitter can not obtain the complete CSI based on the uplink sounding signal.

[16] The present invention focuses on enabling the transmitter to obtain complete downlink CSI by using a CSI feedback channel to aid an uplink sounding signal within one frame.

[17] In the TDD mode, there are two approaches for the transmitter to accurately obtain the pre-coding matrix V. On the one hand, the transmitter can obtain the pre-coding matrix V by applying the SVD to the channel matrix H which is derived from an uplink sounding signal transmitted by the receiver. On the other hand, the transmitter can obtain the information on the pre-coding matrix V from the CSI fed back by the receiver. In the second approach, the pre-coding matrix V is obtained based on a quantized codebook of the CSI fed back by the receiver. It is very applicable in the FDD mode in which the transmitter can only obtain the information on the pre-coding matrix V based on the feedback from the receiver since there is no reciprocity between the uplink and the downlink due to their use of different frequency bands. In the TDD mode, however, there may be channel quantization errors and very large feedback overhead according to the approach by which the pre-coding matrix V is obtained based on the codebook fed back by the receiver. In the TDD mode, the downlink channel impulse response can be obtained by estimating the uplink channel impulse response due to the reciprocity between them.

[18] So far, the channel response for a MIMO-OFDM system in the TDD mode is estimated by inserting discrete pilots into data frames. In order to estimate the channel impulse response matrix H, it is necessary to apply interpolation on the estimated

discrete channel response. In this way, however, accurate channel impulse response H cannot be obtained.

Disclosure of Invention

Technical Solution

[19] Therefore, the object of the present invention is to support SVD-based linear pre-coding technology using an uplink sounding signal in the TDD mode to obtain substantially accurate channel impulse matrix H.

[20] In order to solve the problem mentioned above, a signal communication method for a TDD communication system is provided, comprising steps of: at a transmitter, coding and modulating information bits, multiplying the resulting signal with a pre-coding matrix V and allocating them to OFDM sub-carriers for transmitting via antennas allowable for transmission, wherein the pre-coding matrix V is obtained based on an uplink sounding signal and CSI channel feedback information for the remaining antennas from a receiver; and at the receiver, processing the received signal, estimating a channel matrix H based on a pilot, performing pre-decoding and demodulating based on the estimated matrix H and outputting the resulting information bits.

[21] According to another aspect of the present invention, a TDD communication system is provided, comprising: a transmitter which comprises a channel coding module for coding information bits, a modulating module for modulating the coded information bits, a pre-coding SVD module for multiplying the modulated information bits with a pre-coding matrix V and allocating them to OFDM sub-carriers, and a multi-antenna transmitting module for transmitting the resulting data code elements via antennas allowable for transmission, wherein the pre-coding SVD module is configured to obtain the pre-coding matrix V based on an uplink sounding signal and CSI channel feedback information for the remaining antennas from a receiver; and the receiver for processing the received data code elements, estimating a channel matrix H based on a pilot, performing pre-decoding and demodulating based on the estimated matrix H and outputting the resulting information bits.

[22] According to another aspect of the present invention, a signal transmission method for a TDD communication system is provided, comprising steps of: receiving an uplink sounding signal and CSI channel feedback information for the remaining antennas; generating a pre-coding matrix V based on the received uplink sounding signal and the CSI channel feedback information for the remaining antennas; encoding and modulating information bits, multiplying the resulting signal with the matrix V and allocating them to OFDM sub-carriers for transmitting via antennas allowable for transmission.

[23] According to the present invention, a SVD method is applied in downlink MIMO

pre-coding process, and both the uplink sounding signal and the channel state information (CSI) feedback channel are utilized by the transmitter to estimate the downlink channel impulse response. Also, examples on detailed operation flow are given herein. With the design of the present invention, the problem that the transmitter can not obtain CSI for all transmitting antennas within one frame due to the difference of antenna configurations between the uplink and the downlink in a MIMO system. Meanwhile, the system performance can be improved and the feedback overhead and the complexity of the receiver can be reduced.

Brief Description of Drawings

[24] The above and other aspects, features and advantages of the example embodiments of the present invention will be more apparent from the following detailed description taken conjunction with the drawings in which:

[25] Fig. 1 shows a block diagram of a SVD-based MIMO system;

[26] Fig. 2 shows a block diagram of a SVD pre-coding system based on uplink sounding and CSI feedback according to the present invention;

[27] Fig. 3 shows a frame structure of a system according to the present invention; and

[28] Fig. 4 shows a detailed flow based on uplink sounding and CSI feedback channel information according to the present invention.

Best Mode for Carrying out the Invention

[29] With the present invention, the problem that the transmitter can not obtain the complete CSI in the TDD mode due to the mismatch of antenna configurations between the uplink and the downlink can be addressed. The basic concept of the present invention consists in that the CSI feedback channel can be utilized to aid the uplink sounding signal within one frame such that the transmitter can obtain complete downlink CSI, thereby the problem that the transmitter can not obtain the complete CSI due to the mismatch of antenna configurations between the uplink and the downlink can be addressed.

[30] An uplink sounding signal is generally transmitted in the last code element of an uplink frame. It is mainly used in a TDD system in which a receiver transmits some known code elements to a transmitter for estimating the uplink channel matrix H such that the response of the downlink channel from the transmitter to the receiver can be determined based on the reciprocity between the uplink and the downlink channel in the TDD system. In a conventional method, however, the channel matrix H is obtained at the receiver by means of interpolation based on a pilot inserted into the data code elements by the transmitter. The channel estimated in this way is not accurate enough and the performance of the pre-coding technology is thus degraded.

[31] There are two ways to transmit the uplink sounding signals. The first one is of a

discrete type, in which uplink sounding signals are discretely inserted into the allocated frequency bands. In this way, the channel quality is determined according to the uplink sounding signal transmitted by the receiver and the sub channel with the best quality is selected for data transmission. The other one is to have all sub-carriers within the allocated frequency bands occupied by the receiver. In the present invention, the CSI feedback channel is utilized to aid the uplink sounding signal such that the transmitter can obtain more reliable downlink CSI and that the SVD-based pre-coding technology can thus be supported.

[32] The pre-coding method according to present invention generally consists in that the transmitter transmits a control signal notifying the receiver to perform pre-coding process and requesting the receiver to transmit a uplink sounding signal which occupies all sub-carriers within the allocated sub-band and to feed back CSI for the remaining antennas using a CSI feedback channel. In this way, the problem that the transmitter can not obtain the complete CSI due to the mismatch of antenna configurations between the uplink and the downlink can be addressed. Furthermore, the system performance can be improved and the complexity of the receiver can be reduced. Meanwhile, the method outperforms the pre-coding using a codebook.

[33] According to the present invention, the CSI feedback information is generally transmitted in the CSI feedback channel (such as a sounding domain or a CQICH channel) or a data-specific allocated channel. The CSI feedback information is mainly used, by the receiver, in the quantization and coding of the CSI H_{rest} for the remaining antennas after estimating the CSI matrix H according to the pilot. Then, the CSI matrix H_{rest} for the remaining antennas via which no uplink sounding signal is transmitted is fed back to the transmitter.

[34] The pre-coding scheme according to the present invention is detailed in the following with reference to Figs. 2-4.

[35] The block diagram of the SVD pre-coding system based on uplink sounding in the TDD mode according to the present invention is illustrated in Fig 2. It can be seen in Fig. 2 that the system can comprise a transmitter 100, a receiver 200 and a MIMO channel module 300. The transmitter 100 can comprise a channel coding module, a modulating module, a pre-coding SVD module, an inverse fast Fourier transform (IFFT) module, a multi-antenna transmitting module, a channel estimation module and a channel combining module. The receiver 200 can comprise a multi-antenna receiving module, a fast Fourier transform (FFT) module, a pre-decoding SVD module, a channel decoding module and a channel estimation module.

[36] At the transmitter, information bits are coded first by the channel coding module. The coded data are modulated (baseband modulating) by the modulating module, multiplied with a matrix V for the SVD and finally allocated to OFDM sub-carriers for

transmission. Herein, the matrix V in the SVD can be obtained by combining the uplink sounding signal and CSI channel feedback information for the remaining antennas from the receiver to form the channel matrix H, and calculating the matrix V in the SVD based on the channel matrix H according to the channel reciprocity theory of the TDD system (see H. A. Lorentz, "The theorem of Poynting concerning the energy in the electromagnetic field and two general propositions concerning the propagation of light," Amsterdammer Akademie der Wetenschappen 4 p. 176,1996.) for data code elements transmission, wherein the channel matrix H

$$(\mathbf{H} = [\mathbf{H}_1^T ; \mathbf{H}_{rest}] = \begin{bmatrix} \mathbf{H}_1^T \\ \mathbf{H}_{rest} \end{bmatrix})$$

is derived by combining a channel matrix H_1 (i.e., the channel matrix for the antennas allowable for transmission) estimated based on the uplink sounding signal from the receiver with the fed back CSI H_{rest} for the remaining antennas.

[37] The Data code elements are received by the receiver 200 via the channel. The receiver 200 first applies the Fourier transform to the received data code elements using the FFT module. Then, the channel matrix H can be estimated based on the polit, and the matrix U* can be obtained using SVD. The received data code elements are pre-decoded at the receiver using U* which is obtained using SVD, and then mapped into bit stream by the demodulating module. The bit data are subjected to error correction in the channel decoding module to finally output the information bits.

[38] Design of the frame structure of the system

[39] The frame structure of the system according to the present invention is illustrated in Fig. 3. It can be seen in Fig. 3 that the frame structure of the system consists of six parts: a control channel sub-frame, a pilot sequence, a downlink payload, an uplink payload, an uplink sounding signal and a feedback channel. Using the control channel sub-frame, the transmitter 100 requests the receiver 200 to transmit an uplink sounding and feed back the CSI for the remaining antennas via the feedback channel, and notifies the receiver to prepare for pre-coding receiving. After receiving the control channel sub-frame, the receiver transmits the uplink sounding signal and the feedback information in the uplink. After receiving the uplink sounding signal and the feedback channel information, the transmitter estimates the downlink channel response matrix H to obtain the transmitting matrix V in the SVD. Next, the transmitter 100 begins to transmit the pilot sequence and the downlink payload. The receiver 200 pre-decodes the downlink payload after receiving it.

[40] The specific flow based on the uplink sounding and the CSI feedback channel information according to present invention will be detailed with reference to Fig. 2 and 4. It can be seen in Fig. 4 that the transmitter 100 first transmits a control signal to the receiver 200, requesting the receiver to transmit the uplink sounding signal and the CSI feedback information in the j-th frame (Frame(j)) via all sub-carriers within the allocated sub-band. Herein, the control channel sub-frame in the j-th frame (Frame(j)) for the downlink can be used to transmit the control signal.

[41] After receiving the control signal, the receiver transmits the uplink sounding signal in the j-th frame (Frame(j)) for the uplink via all sub-carriers within the allocated sub-band, estimates the complete CSI H according to the pilot the j-th frame (Frame(j)), and quantizes the CSI H_{rest} for the remaining antennas via which no uplink sounding signal is transmitted. Then, the CSI H_{rest} for the remaining antennas, via which no uplink sounding signal is transmitted, can be fed back using the CSI feedback channel. After receiving the uplink sounding and the CSI feedback information H_{rest}, the transmitter estimates the channel matrix H1 based on the uplink sounding, where H_1 represents the channel matrix estimated based on the uplink sounding. With reciprocity ($H_{DL}=H_{UL}^T$) between the uplink and the downlink channel in the TDD system (H. A. Lorentz, "The theorem of Poynting concerning the energy in the electromagnetic field and two general propositions concerning the propagation of light," Amsterdammer Akademie der Wetenschappen 4 p. 176,1996.), H_1 and H_{rest} can be combined to form the channel matrix $H(H=[H_1^T;H_r])$. Next, the transmitter calculates the pre-coding matrix V in the pre-coding SVD from the channel matrix H, then perform pre-coding on the data section in the (j+1)-th frame. Finally, the pre-coded data section is allocated to the OFDM sub-carriers for transmission.

[42] After receiving the (j+1)-th frame, the receiver 200 performs OFDM demodulation using FFT, and estimates the channel matrix H based on the pilot in the j-th frame (Frame(j)) so as to calculate the matrix U* in the SVD (i.e., the pre-decoding matrix at the receiver). Meanwhile, the receiver 200 pre-decodes the data in the (j+1)-th frame (Frame(j+1)) using the calculated matrix U*.

[43] In an IEEE 802.16m system which operates in the TDD mode, it is necessary for a MS to accurately know the downlink (BS→MS) channel response in real time when transmitting data via the same channel for a long duration. In this case, the MS can to transmit an uplink sounding signal to facilitate the estimation of the channel response H. However, it is required that the system has two transmitting antennas and two receiving antennas in the downlink and one transmitting antenna and two receiving antennas in the uplink, therefore, complete downlink CSI cannot be obtained based on the uplink sounding signal due to the difference of MIMO configurations between the uplink and the downlink. Thus, it is necessary to utilize the CSI feedback channel to

feed back the CSI for the remaining antenna.

[44] The application of the present invention can be generalized to a MIMO system with N_t transmitting antennas and N_r receiving antennas, where $N_t > N_r$. The system may be required to have N_t transmitting antennas and N_r receiving antennas in the downlink, and N_k ($N_k < N_r$) transmitting antennas and N_t receiving antennas in the uplink. Therefore, complete downlink CSI cannot be obtained based on the uplink sounding signal due to the difference of MIMO configurations between the uplink and the downlink. Thus, it is necessary to utilize the CSI feedback channel to feed back the CSI for the remaining (N_r-N_k) antennas.

[45] Therefore, according to the present invention, it is possible to enable a transmitter to obtain complete downlink CSI by using a CSI feedback channel to aid an uplink sounding signal within one frame. Accordingly, the problem that the transmitter can not obtain the complete CSI due to the mismatch of antenna configurations between the uplink and the downlink can be addressed. Furthermore, the system performance can be improved and the complexity of the receiver can be reduced. Meanwhile, the inventive method outperforms the pre-coding using a codebook.

[46] In addition, the channel feedback overhead and channel quantization errors can be reduced according to the uplink sounding signal employed in the present invention.

[47] The channel estimation based on the uplink sounding signal, which occupies all sub-carriers within the allocated sub-band, is more accurate than the pilot-based channel estimation. The pre-coding performance is thus improved.

[48] The present invention enables a transmitter to obtain complete downlink CSI by using a CSI feedback channel to aid an uplink sounding signal within one frame. Accordingly, the problem that the transmitter can not obtain the complete CSI due to the mismatch of antenna configurations between the uplink and the downlink can be addressed. The uplink sounding signal is generally transmitted in the last code element of an uplink frame. The CSI feedback information is generally transmitted in a CSI feedback channel or a data-specific allocated channel.

[49] Further, in future MIMO systems, the number of antennas at the transmitter can be greater than that at the receiver, resulting in a mismatch of antenna configurations between the uplink and the downlink. Thus, there is a problem to be solved that the transmitter can not obtain the complete CSI based on the uplink sounding signal. Thus, a method for enabling a transmitter to obtain complete downlink CSI by using a CSI feedback channel to aid an uplink sounding signal within one frame is provided. With this method, the problem that the transmitter can not obtain the complete CSI due to the mismatch of antenna configurations between the uplink and the downlink can be addressed. Furthermore, the system performance can be improved and the complexity of the receiver can be reduced. Meanwhile, the method outperforms the pre-coding

using a codebook.

[50] Although the invention has been described in accordance with the particular embodiments thereof, it will be understood by those skilled in the art that various modifications may be made in forms and details without departing from the spirit and scope of the present invention defined by the appended claims and the equivalents thereof.

Claims

[1] A signal communication method for a Time Division Duplex (TDD) communication system, comprising steps of:
at a transmitter, coding and modulating information bits, multiplying the resulting signal with a pre-coding matrix V and allocating them to OFDM sub-carriers for transmitting via antennas allowable for transmission, wherein the pre-coding matrix V is obtained based on an uplink sounding signal and Channel State Information (CSI) channel feedback information for the remaining antennas from a receiver; and
at the receiver, processing the received signal, estimating a channel matrix H based on a pilot signal, performing pre-decoding and demodulating based on the estimated matrix H and outputting the resulting information bits.

[2] The signal communication method according to claim 1, wherein the pre-coding matrix V is obtained at the transmitter by:
estimating a first matrix based on the received uplink sounding signal,
combining the first matrix and the CSI channel feedback information for the remaining antennas to form the channel matrix H, and
processing the channel matrix H according to a channel reciprocity theory for the TDD system.

[3] The signal communication method according to claim 1, further comprising:
the transmitter transmits a control signal notifying the receiver to transmit the uplink sounding signal which occupies all sub-carriers within the allocated sub-band and to feed back the CSI for the remaining antennas via a CSI feedback channel.

[4] The signal communication method according to claim 3, wherein after receiving the notification from the transmitter, the receiver estimates, based on the pilot signal in the current frame, and quantizes the CSI H_{rest} for the remaining antennas via which no up sounding signal is transmitted, as the CSI channel feedback information.

[5] A Time Division Duplex (TDD) communication system, comprising:
a transmitter which includes a channel coding module for coding information bits, a modulating module for modulating the coded information bits, a pre-coding SVD module for multiplying the modulated information bits with a pre-coding matrix V and allocating them to OFDM sub-carriers, and a multi-antenna transmitting module for transmitting the resulting data code elements via antennas allowable for transmission, wherein the pre-coding SVD module is configured to obtain the pre-coding matrix V based on an uplink sounding signal

and Channel State Information (CSI) channel feedback information for the remaining antennas from a receiver; and
the receiver for processing the received data code elements, estimating a channel matrix H based on a pilot, performing pre-decoding and demodulating based on the estimated matrix H and outputting the resulting information bits.

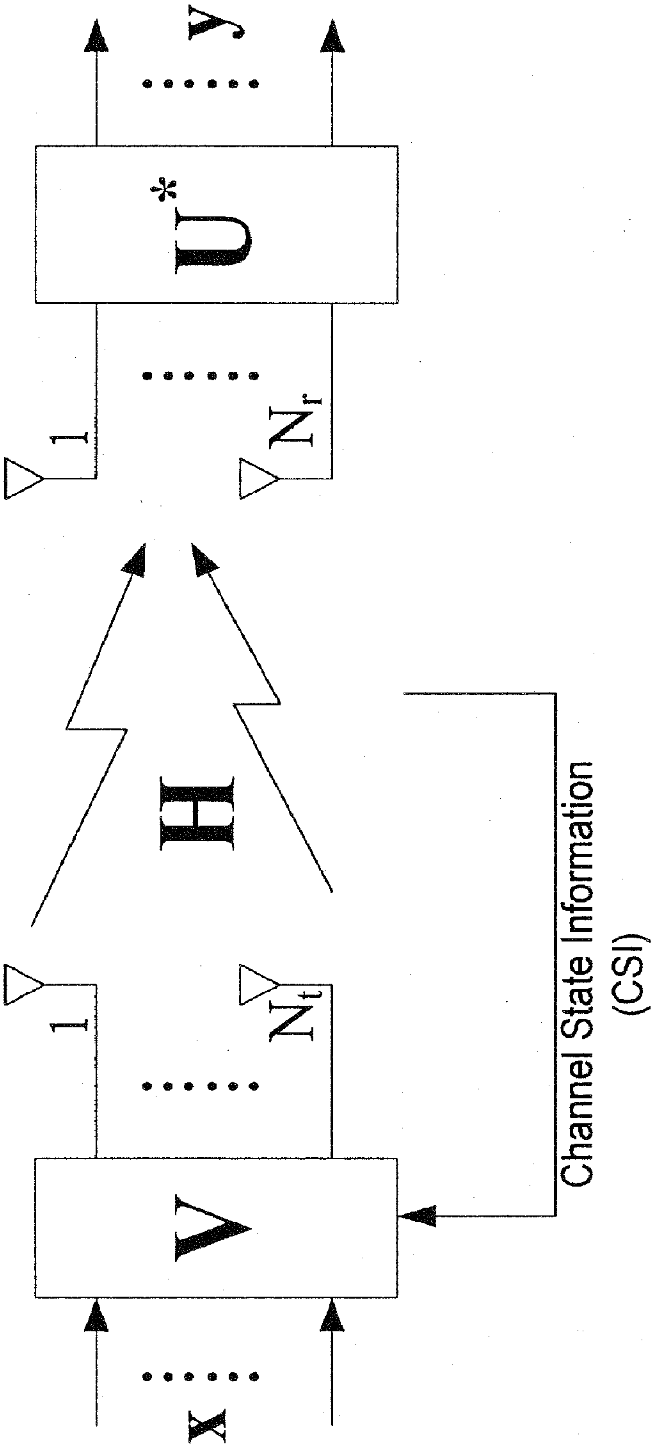
[6] The communication system according to claim 5, wherein the transmitter is configured to obtain the pre-coding matrix V by:
estimating a first matrix based on the received uplink sounding signal,
combining the first matrix and the CSI channel feedback information for the remaining antennas to form the channel matrix H, and
processing the channel matrix H according to a channel reciprocity theory for the TDD system.

[7] The communication system according to claim 5, wherein the transmitter transmits a control signal notifying the receiver to transmit the uplink sounding signal which occupies all sub-carriers within the allocated sub-band and to feed back the CSI for the remaining antennas via a CSI feedback channel.

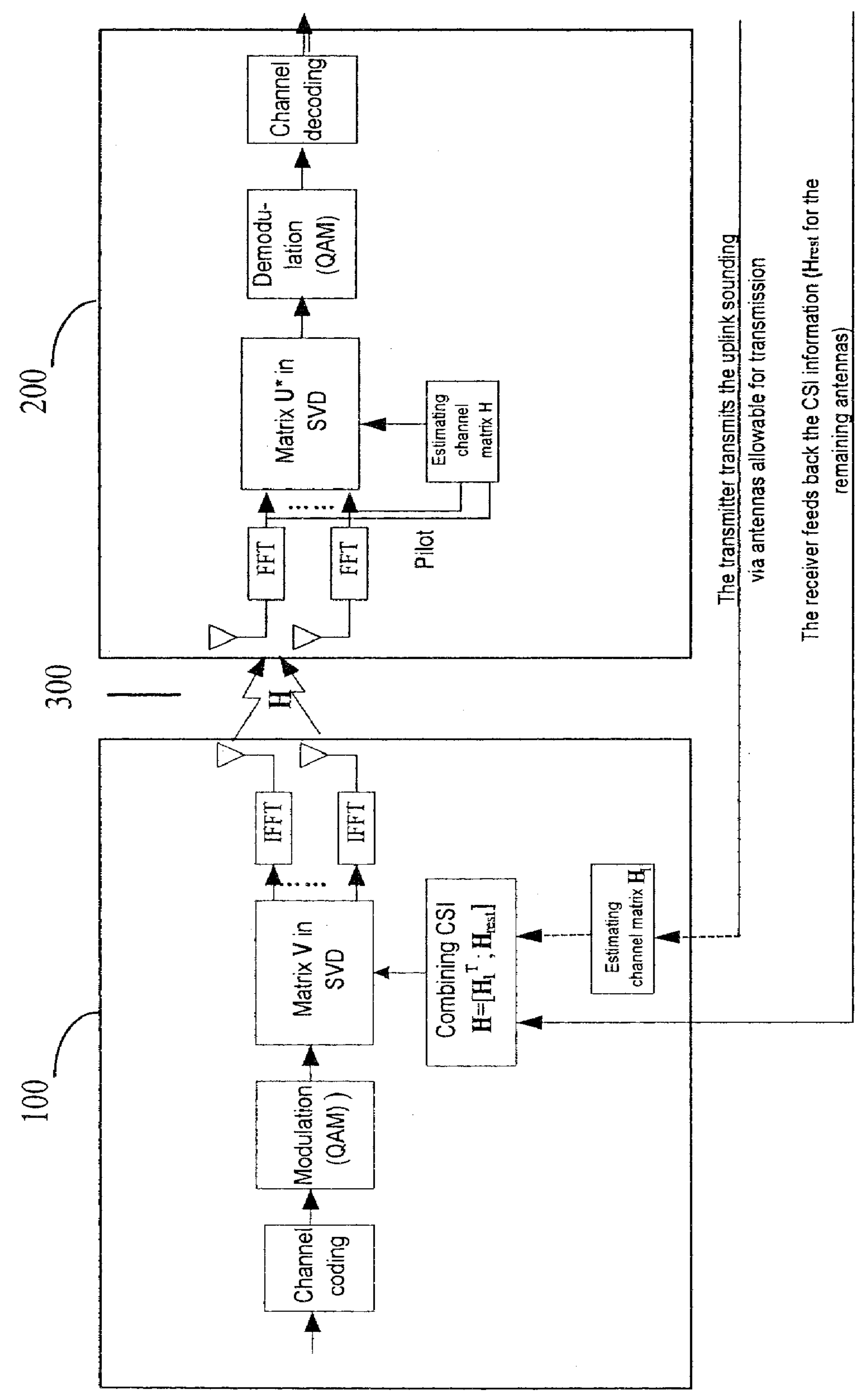
[8] The communication system according to claim 7, wherein after receiving the notification from the transmitter, the receiver estimates, based on the pilot in the current frame, and quantizes the CSI H_{rest} for the remaining antennas via which no up sounding signal is transmitted, as the CSI channel feedback information.

[9] A signal transmission method for a Time Division Duplex (TDD) communication system, comprising steps of:
receiving an uplink sounding signal and Channel State Information (CSI) channel feedback information for the remaining antennas;
generating a pre-coding matrix V based on the received uplink sounding signal and the CSI channel feedback information for the remaining antennas;
encoding and modulating information bits, multiplying the resulting signal with the matrix V and allocating them to OFDM sub-carriers for transmitting via antennas allowable for transmission.

[Fig. 1]

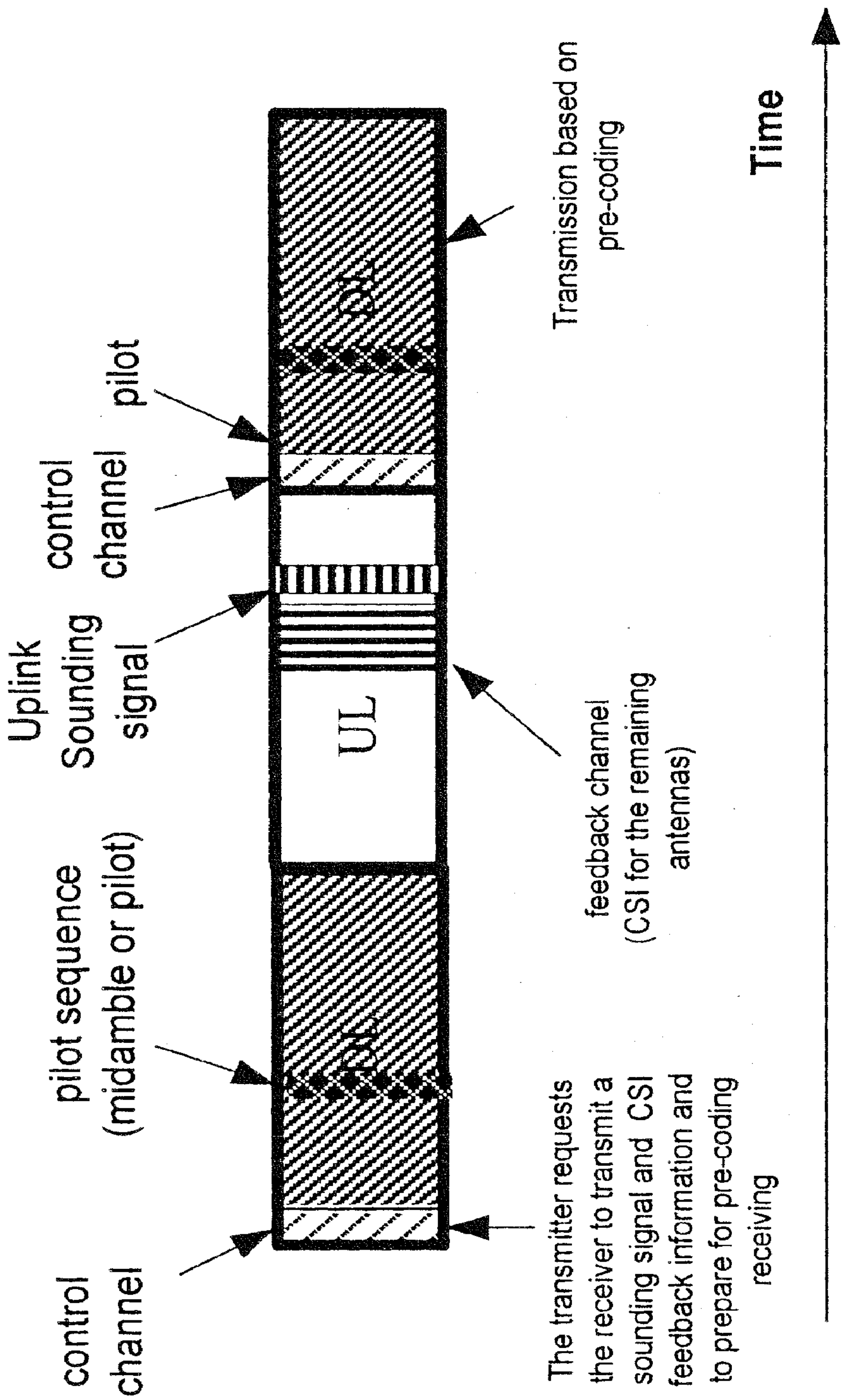


[Fig. 2]

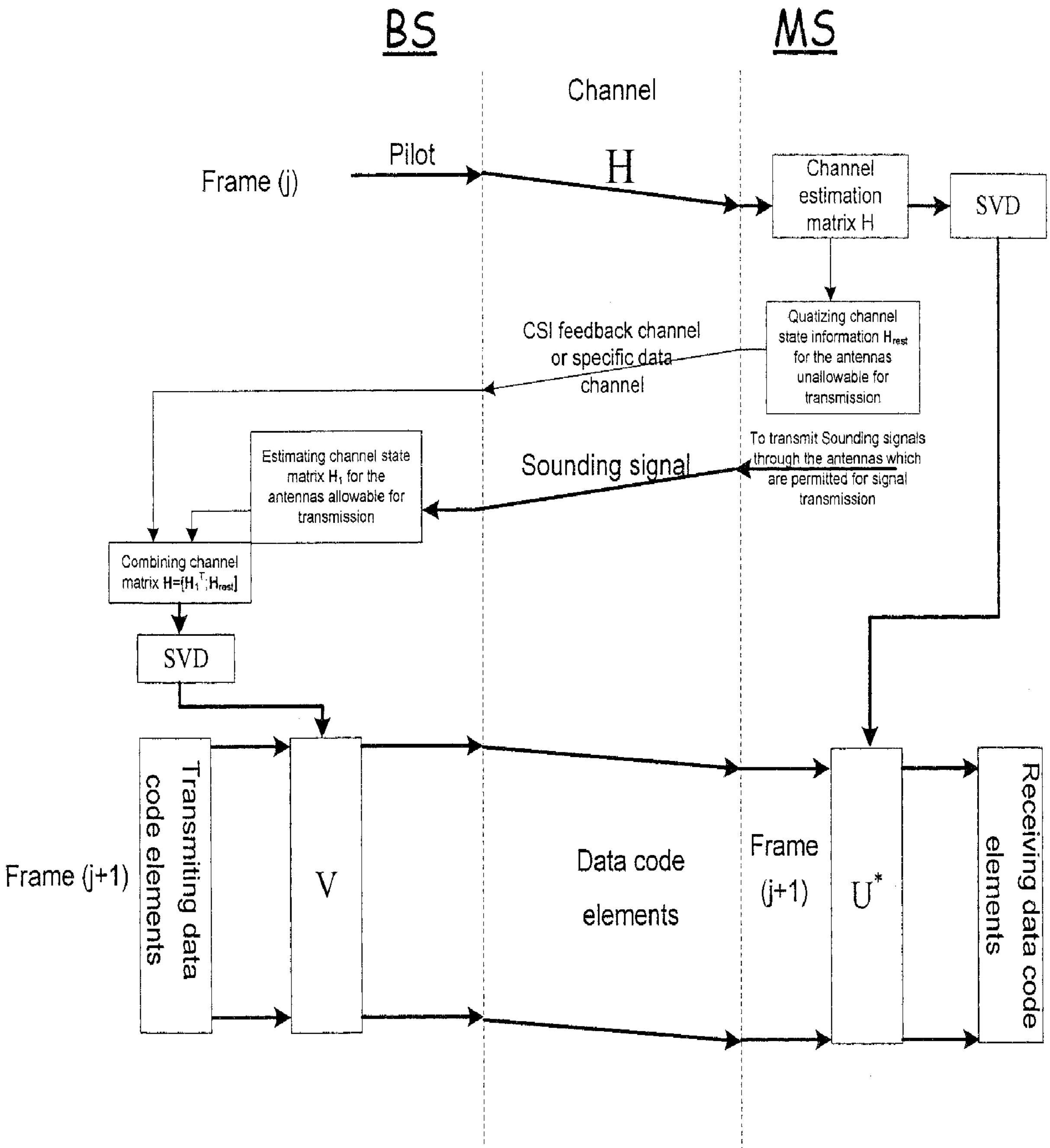


200
300
100
Channel decoding
Demodu-lation (QAM)
Matrix U* in SVD
Estimating channel matrix H
FFT
FFT
Pilot
H
IFFT
IFFT
Matrix V in SVD
Combining CSI $\mathbf{H}=[\mathbf{H}_1^T ; \mathbf{H}_{rest}]$
Estimating channel matrix $\mathbf{H}_1$
Modulation (QAM))
Channel coding
The transmitter transmits the uplink sounding via antennas allowable for transmission
The receiver feeds back the CSI information ($\mathbf{H}_{rest}$ for the remaining antennas)

[Fig. 3]


control channel
pilot sequence (midamble or pilot)
Uplink Sounding signal
control channel
pilot
DL
UL
DL
The transmitter requests the receiver to transmit a sounding signal and CSI feedback information and to prepare for pre-coding receiving
feedback channel (CSI for the remaining antennas)
Transmission based on pre-coding
Time

[Fig. 4]


BS
MS
Channel
Pilot
Frame (j)
H
Channel estimation matrix H
SVD
Quatizing channel state information H rest for the antennas unallowable for transmission
CSI feedback channel or specific data channel
To transmit Sounding signals through the antennas which are permitted for signal transmission
Sounding signal
Estimating channel state matrix H1 for the antennas allowable for transmission
Combining channel matrix H=[H1T;Hrest]
SVD
Frame (j+1)
Transmiting data code elements
V
Data code elements
Frame (j+1)
U*
Receiving data code elements