

SUMMARY

[0004] In general, example embodiments of the present disclosure provide a solution for Uplink Control Information (UCI) design.

[0004a] In an aspect, there is a method comprising determining (510), at a terminal device (120), a matrix $\widetilde{\mathbf{W}}_2$ comprising linear combination coefficients for a pre-coder matrix indicator, PMI, matrix, wherein:

the PMI matrix is represented by $\mathbf{W} = \mathbf{W}_1 \widetilde{\mathbf{W}}_2 \mathbf{W}_f^H$,

matrix $\mathbf{W}_1$ represents components of a spatial domain orthogonal basis, matrix $\mathbf{W}_f$ represents components of a frequency domain orthogonal basis, and matrix $\widetilde{\mathbf{W}}_2$ has spatial components and frequency components;

characterized by

determining a shifted matrix by shifting (520) the frequency components of matrix $\widetilde{\mathbf{W}}_2$ circularly, such that a maximum coefficient of matrix $\widetilde{\mathbf{W}}_2$ is located in a frequency component with a predetermined index;

generating (530) a strongest coefficient indicator indicating the spatial component associated with the maximum coefficient of matrix $\widetilde{\mathbf{W}}_2$; and

transmitting (540), to a network device (110), uplink control information comprising the strongest coefficient indicator and non-zero coefficients of the shifted matrix, wherein the transmitted non-zero coefficients exclude the maximum coefficient.

[0004b] In an aspect, there is method comprising receiving (610), at a network device (110) and from a terminal device (120), uplink control information comprising a strongest coefficient indicator and non-zero coefficients of a matrix $\widetilde{\mathbf{W}}_2$ for a pre-coder matrix indicator, PMI, matrix, wherein:

the PMI matrix is represented by $\mathbf{W} = \mathbf{W}_1 \widetilde{\mathbf{W}}_2 \mathbf{W}_f^H$,

matrix $\mathbf{W}_1$ represents components of a spatial domain orthogonal basis, matrix $\mathbf{W}_f$ represents components of a frequency domain orthogonal basis, matrix $\widetilde{\mathbf{W}}_2$ has spatial components and frequency components, and

wherein the received non-zero coefficients exclude a maximum coefficient;

characterized in that

the received strongest coefficient indicator indicates a spatial component associated with a maximum coefficient of matrix $\widetilde{\mathbf{W}}_2$, and in that the method comprises:

determining (620) state information of the channel, wherein a coefficient of matrix

$\widetilde{\mathbf{W}}_2$, at a position with the spatial component indicated by the strongest coefficient indicator and with a frequency component determined by a predetermined index, assumes a preconfigured value obtained by applying a common scaling to the coefficients of the matrix $\widetilde{\mathbf{W}}_2$.

[0004c] In an aspect, there is a terminal device comprising at least one processor; and at least one memory including computer program codes;

the at least one memory and the computer program codes are configured to, with the at least one processor, cause the terminal device at least to:

determine a matrix $\widetilde{\mathbf{W}}_2$ comprising linear combination coefficients, for a pre-coder matrix indicator, PMI, matrix, wherein:

the PMI matrix is represented by $\mathbf{W} = \mathbf{W}_1 \widetilde{\mathbf{W}}_2 \mathbf{W}_f^H$,

matrix $\mathbf{W}_1$ represents components of a spatial domain orthogonal basis, matrix $\mathbf{W}_f$ represents components of a frequency domain orthogonal basis, and the matrix $\widetilde{\mathbf{W}}_2$ has spatial components and frequency components;

characterized in that the terminal device is caused to

determine a shifted matrix by shifting the frequency components of matrix $\widetilde{\mathbf{W}}_2$ circularly, such that a maximum coefficient of matrix $\widetilde{\mathbf{W}}_2$ is located in a frequency component with a predetermined index;

generate a strongest coefficient indicator indicating the spatial component associated with the maximum coefficient of matrix $\widetilde{\mathbf{W}}_2$; and

transmit, to a network device (110), uplink control information comprising the strongest coefficient indicator and non-zero coefficients of the shifted matrix, wherein the transmitted non-zero coefficients exclude the maximum coefficient.

[0004d] In an aspect, there is a network device comprising at least one processor; and at least one memory including computer program codes;

the at least

vice (120), uplink control information comprising a strongest coefficient indicator and nonone memory and the computer program codes are configured to, with the at least one processor, cause the network device at least to:

receive, from a terminal de-zero coefficients of a matrix $\widetilde{\mathbf{W}}_2$ for a pre-coder matrix indicator, PMI, matrix, wherein:

the PMI matrix is represented by $\mathbf{W} = \mathbf{W}_1 \widetilde{\mathbf{W}}_2 \mathbf{W}_f^H$,

matrix $\mathbf{W}_1$ represents components of a spatial domain orthogonal basis, matrix $\mathbf{W}_f$

represents components of a frequency domain orthogonal basis, matrix $\widetilde{W}_2$ has spatial components and frequency components, and

wherein the received non-zero coefficients exclude a maximum coefficient;

characterized in that

the received strongest coefficient indicator indicates a spatial component associated with a maximum coefficient of matrix $\widetilde{W}_2$, and in that the device is caused to:

determine state information of the channel, wherein a coefficient of matrix $\widetilde{W}_2$ assumes a value of 1 at a position determined by the strongest coefficient indicator and a predetermined index of the matrix $\widetilde{W}_2$

[0005] In an embodiment, there is provided a method. The method comprises determining, at a terminal device, a matrix comprising a set of non-zero linear combination coefficients for quantizing a channel between the terminal device and a network device, the matrix having spatial components and frequency components; shifting the frequency components of the matrix circularly, such that a target coefficient of the set of non-zero linear combination coefficients is located in a frequency component with a predetermined index of the frequency components in a shifted matrix; generating a first indication indicating the spatial component associated with the target coefficient in the matrix; and transmitting, to the network device, uplink control information comprising the first indication.

[0006] In an embodiment, there is provided a method. The method comprises receiving, at a network device and from a terminal device, uplink control information comprising a first indication, the first indication indicating spatial components associated with a target coefficient in a matrix comprising a set of non-zero linear combination coefficients for quantizing a channel between the terminal device and the network device, the matrix having the spatial components and frequency components; and determining state information of the channel based on the uplink control information.

[0007] In an embodiment, there is provided a device. The device comprises at least one processor; and at least one memory including computer program codes; the at least one memory and the computer program codes are configured to, with the at least one processor, cause the device at least to determine, at a terminal device, a matrix comprising a set of non-zero linear combination coefficients for quantizing a channel between the terminal device and a network device, the matrix having spatial components and frequency components; shift the frequency components of the matrix circularly, such that a target coefficient of the set of non-

[0008] zero linear combination coefficients is located in a frequency component with a predetermined index of the frequency components in a shifted matrix; generate a first indication indicating the spatial component associated with the target coefficient in the matrix; and transmit, to the network device, uplink control information comprising the first indication.

[0009] In an embodiment, there is provided a device. The device comprises at least one processor; and at least one memory including computer program codes; the at least one memory and the computer program codes are configured to, with the at least one processor, cause the device at least to receive, at a network device and from a terminal device, uplink control information comprising a first indication, the first indication indicating spatial components associated with a target coefficient in a matrix comprising a set of non-zero linear combination coefficients for quantizing a channel between the terminal device and the network device, the matrix having the spatial components and frequency components; and determine state information of the channel based on the uplink control information..

[0010] In an embodiment, there is provided an apparatus comprises means for determining, at a terminal device, a matrix comprising a set of non-zero linear combination coefficients for quantizing a channel between the terminal device and a network device, the matrix having spatial components and frequency components; means for shifting the frequency components of the matrix circularly, such that a target coefficient of the set of non-zero linear combination coefficients is located in a frequency component with a predetermined index of the frequency components in a shifted matrix; means for generating a first indication indicating the spatial component associated with the target coefficient in the matrix; and means for transmitting, to the network device, uplink control information comprising the first indication.

[0011] In an embodiment, there is provided an apparatus comprising means for receiving, at a network device and from a terminal device, uplink control information comprising a first indication, the first indication indicating spatial components associated with a target coefficient in a matrix comprising a set of non-zero linear combination coefficients for quantizing a channel between the terminal device and the network device, the matrix having the spatial components and frequency components; and means for determining state information of the channel based on the uplink control information.

[0012] In an embodiment, there is provided a computer readable medium having a computer program stored thereon which, when executed by at least one processor of a device, causes the device to carry out the method according to the first aspect.

[0013] In an embodiment, there is provided a computer readable medium having a computer program stored thereon which, when executed by at least one processor of a device, causes the device to carry out the method according to the second aspect.