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(54) Title: SOUNDING REFERENCE SIGNALS (SRS) IN NEW RADIO (NR) COMMUNICATION SYSTEMS

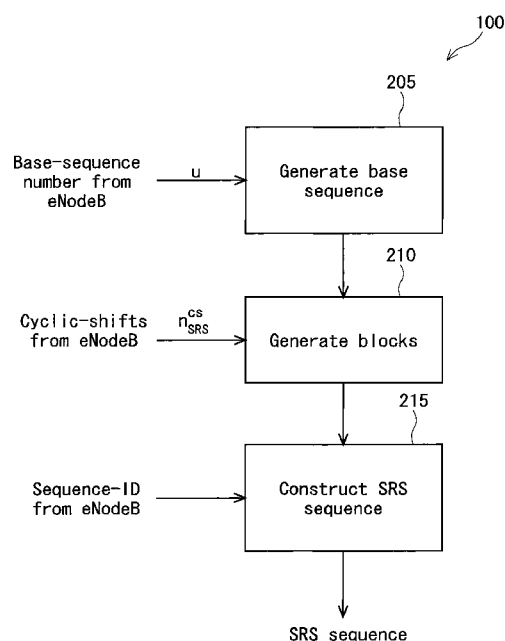


Fig. 2

(57) Abstract: A New Radio (NR) system and a method for transmitting sounding reference signals in a new radio communications system is provided that enables mutual orthogonality to be maintained between SRS resources of different UEs. The system includes an eNodeB and a plurality of UEs, and the method includes: generating, at a UE, a base sequence based upon a sequence number received from the eNodeB; generating a plurality of blocks from the base sequence by applying cyclic-shifts to the base sequence; and generating a sounding reference signal by concatenating the cyclically shifted blocks. The sounding reference signal is then transmitted to the eNodeB. By using the same Zadoff-Chu base sequence with different cyclic shifts among overlapped UEs, mutual orthogonality of the SRS of each UE is maintained.

DESCRIPTION**Title of Invention**

SOUNDING REFERENCE SIGNALS (SRS) IN NEW RADIO (NR)
COMMUNICATION SYSTEMS

5

Technical Field

[0001]

The present invention relates to channel quality signalling in advanced wireless communication networks, and in particular in New Radio (NR) Multi-User Multiple Input

10 Multiple Output (MU-MIMO) communication systems.

[0002]

The following abbreviations are used herein.

LTE	Long Term Evolution
MIMO	Multiple Input Multiple Output
MU	Multiple User
NR	New Radio
PRB	Physical Resource Block
UE	User Equipment
RE	Resource Element
SRS	Sounding Reference Signal
ZC	Zadoff Chu
N_{sc}^{RB}	Number of subcarriers in a Physical Resource Block (normally 12 subcarriers)

Background Art

15

[0003]

Wireless communication systems are widely known in which base stations (also known as eNodeBs (eNBs)) communicate with mobile devices (also known as user equipments (UEs)) which are within range of the eNodeB. Each eNodeB divides its available bandwidth, i.e. frequency and time resources, into different resource allocations for the different UEs.

20

[0004]

In order to efficiently utilise the bandwidth, the eNodeB may, among other things, estimate the uplink channel quality and use this information for uplink scheduling. Sounding reference signals (SRS) are one way of measuring uplink channel quality in existing LTE

systems.

[0005]

Much attention has now, however, been focused on the development of next generation technology and services, and in particular to new radio (NR) systems. These NR systems are developed to both satisfy urgent market needs, together with more long-term requirements, and are thus very broad.

[0006]

The use of LTE-like sounding reference signalling methods in NR systems has been considered in 3GPP TSG Radio Access Network (RAN) in the development of NR systems.

However, LTE-like sounding reference signalling methods are considered to provide inflexible signalling. In particular, it is suggested that severe scheduling restrictions would be required to ensure mutual orthogonality amongst all users. Such severe scheduling restrictions are clearly undesirable.

[0007]

As such, there is clearly a need for an improved method for transmitting sounding reference signals in a new radio (NR) communication system.

[0008]

It will be clearly understood that, if a prior art publication is referred to herein, this reference does not constitute an admission that the publication forms part of the common general knowledge in the art in Australia or in any other country.

Summary of Invention

[0009]

The present invention is directed to method for transmitting sounding reference signals in a new radio (NR) communication system, which may at least partially overcome at least one of the abovementioned disadvantages or provide the consumer with a useful or commercial choice.

[0010]

With the foregoing in view, the present invention in one form, resides broadly in a method for transmitting sounding reference signals in a new radio communications system including an eNodeB and a plurality of UEs, the method including:

generating, at a UE, a base sequence based upon a sequence number received from the eNodeB;

generating a plurality of blocks from the base sequence by applying cyclic-shifts to the

base sequence;

generating a sounding reference signal by concatenating the cyclically shifted blocks;

and

transmitting the sounding reference signal to the eNodeB,

- 5 wherein the plurality of blocks comprises 48 orthogonal blocks, and each of the plurality of blocks is 4 Physical Resource Blocks (PRBs) long.

[0011]

Advantageously, the method enables mutual orthogonality to be maintained between SRS resources of the different UEs, which in turn enables more accurate uplink channel quality
10 estimation. Furthermore, the method is aligned with existing LTE-based methods.

[0012]

The base sequence $\bar{r}_{u,v}$ may be determined according to 3GPP specification TS 36.211 V14.1.0 (2016-12), Section 5.5.1.1.

[0013]

- 15 Preferably, the base sequence $\bar{r}_{u,v}$ is determined according to:

$$\bar{r}_{u,v}(n) = x_q(n \bmod N_{\text{ZC}}^{\text{RS}}), \quad 0 \leq n < M_{\text{sc}}^{\text{RS}} \quad \text{with } u \in \{0, 1, \dots, 29\}$$

where the q^{th} root ZC sequence is defined by

$$x_q(m) = e^{-j \frac{\pi q m(m+1)}{N_{\text{ZC}}^{\text{RS}}}}, \quad 0 \leq m \leq N_{\text{ZC}}^{\text{RS}} - 1$$

with q given by

$$20 \quad q = \lfloor \bar{q} + 1/2 \rfloor + v \cdot (-1)^{\lfloor 2\bar{q} \rfloor}$$

$$\bar{q} = N_{\text{ZC}}^{\text{RS}} \cdot (u + 1) / 31$$

and where $M_{\text{sc}}^{\text{RS}} = 4N_{\text{sc}}^{\text{RB}} = 48$, $N_{\text{ZC}}^{\text{RS}} = 47$ and $v = 0$.

[0014]

The cyclically-shifted base sequence $r_{u,v}^{(\alpha_{\bar{p}})}(n)$ may be determined according to 3GPP specification TS 36.211 V14.1.0 (2016-12), Section 5.5.3.1.

- 25 [0015]

Preferably, the cyclically-shifted base sequence $r_{u,v}^{(\alpha_{\bar{p}})}(n)$ is determined according to:

$$r_{u,v}^{(\alpha_{\bar{p}})}(n) = e^{j\alpha_{\bar{p}}n} \bar{r}_{u,v}(n), \quad 0 \leq n < M_{\text{sc}}^{\text{RS}}$$

where $\alpha_{\bar{p}}$ is the cyclic shift.

[0016]

Preferably, the cyclic shift $\alpha_{\tilde{p}}$ is determined according to:

$$\alpha_{\tilde{p}} = 2\pi \frac{n_{\text{SRS}}^{\text{cs}, \tilde{p}}}{n_{\text{SRS}}^{\text{cs}, \text{max}}}$$

$$n_{\text{SRS}}^{\text{cs}, \tilde{p}} = \left(n_{\text{SRS}}^{\text{cs}} + \frac{n_{\text{SRS}}^{\text{cs}, \text{max}} \tilde{p}}{N_{\text{ap}}} \right) \bmod n_{\text{SRS}}^{\text{cs}, \text{max}},$$

$$\tilde{p} \in \{0, 1, \dots, N_{\text{ap}} - 1\}$$

where $n_{\text{SRS}}^{\text{cs}} \in \{0, 1, \dots, n_{\text{SRS}}^{\text{cs}, \text{max}}\}$ and N_{ap} is the number of antenna ports used for sounding

5 reference signal transmission.

[0017]

Preferably, the blocks are concatenated according to an instruction received from the eNodeB.

[0018]

10 Preferably, the sounding reference signal is transmitted such that blocks thereof are aligned with blocks of sounding reference signals of other UEs.

[0019]

Preferably, the cyclic shift used by each UE at each block is signalled by the eNodeB to the UEs.

15 [0020]

Preferably, different cyclic shifts are used by different UEs in corresponding blocks. Preferably, the same base sequence is used by the UEs in corresponding blocks.

[0021]

20 Preferably, the eNodeB is configured to schedule SRS resources at each of the UEs such that mutual orthogonality is maintained between the SRS resources of the different UEs.

[0022]

In another form, the invention resides broadly in a new radio communications systems including an eNodeB and a plurality of UEs, wherein each UE is configured to:

25 generate, a base sequence based upon a sequence number received from the eNodeB;
generate a plurality of blocks from the base sequence by applying cyclic-shifts to the base sequence;

generate a sounding reference signal by concatenating the cyclically shifted blocks; and transmit to the sounding reference signal to the eNodeB.

[0023]

Any of the features described herein can be combined in any combination with any one or more of the other features described herein within the scope of the invention.

[0024]

The reference to any prior art in this specification is not, and should not be taken as an
5 acknowledgement or any form of suggestion that the prior art forms part of the common general knowledge.

Brief Description of Drawings

[0025]

10 Various embodiments of the invention will be described with reference to the following drawings.

[0026]

[Fig. 1]

Fig. 1 illustrates a MU-MIMO system, according to an embodiment of the present
15 invention.

[0027]

[Fig. 2]

Fig. 2 illustrates a method of generating an Sounding Reference Signal (SRS) sequence at a UE, for transmission to the eNodeB 105, according to an embodiment of the present
20 invention.

[0028]

[Fig. 3]

Fig.3 illustrates an exemplary SRS sequence transmission diagram 300, according to an embodiment of the present invention.

25 [0029]

Preferred features, embodiments and variations of the invention may be discerned from the following Description of Embodiments which provides sufficient information for those skilled in the art to perform the invention. The Description of Embodiments is not to be regarded as limiting the scope of the preceding Summary of the Invention in any way.

30

Description of Embodiments

[0030]

Fig. 1 illustrates a MU-MIMO system 100, according to an embodiment of the present invention. The MU-MIMO system 100 includes an eNodeB 105 including a plurality of

antennas 110. The eNodeB 105 is configured to communicate with a plurality of different UEs 120, each equipped with multiple antennas 125.

[0031]

As outlined in further detail below, the UEs 120 transmit sounding reference signals (SRS) to the eNodeB 105 to enable the eNodeB 105 to estimate the UL channel quality. In short, the SRS comprise sequences known to the eNodeB 105, transmitted from the UEs 120 in the UL direction, enabling the eNodeB 105 to estimate UL channel quality based upon reception thereof.

[0032]

The eNodeB 105 schedules SRS resources, and can schedule SRS resources to multiple UEs 120 such that the resources comprise fully and/or partially overlapping in SRS time-frequency resource elements (REs). The SRS are Zadoff Chu (ZC) based, and multiple SRS resources can share the same root sequence values in the overlapping REs, which allows for low or zero mutual cross-correlation.

[0033]

Fig. 2 illustrates a method 200 of generating an SRS sequence at a UE 120, for transmission to the eNodeB 105, according to an embodiment of the present invention.

[0034]

Initially, and at step 205, a base sequence $\bar{r}_{u,v}$ is generated based upon a base sequence number $u \in \{0,1,\dots,29\}$ received from the eNodeB 105.

[0035]

In particular, the base sequence $\bar{r}_{u,v}(0), \dots, \bar{r}_{u,v}(M_{sc}^{RS} - 1)$ is given by

$$\bar{r}_{u,v}(n) = x_q(n \bmod N_{ZC}^{RS}), \quad 0 \leq n < M_{sc}^{RS}$$

where the q^{th} root ZC sequence is defined by

$$x_q(m) = e^{-j \frac{\pi q m(m+1)}{N_{ZC}^{RS}}}, \quad 0 \leq m \leq N_{ZC}^{RS} - 1$$

with q given by

$$q = \lfloor \bar{q} + 1/2 \rfloor + v \cdot (-1)^{\lfloor 2\bar{q} \rfloor}$$

$$\bar{q} = N_{ZC}^{RS} \cdot (u + 1) / 31$$

[0036]

Here $M_{sc}^{RS} = 4N_{sc}^{RB} = 48$, $N_{ZC}^{RS} = 47$ and $v = 0$ (due to $M_{sc}^{RS} < 6N_{sc}^{RB}$).

[0037]

At step 210, a plurality of blocks are generated from the base sequence. In particular, cyclic-shifts $n_{\text{SRS}}^{\text{cs}} \in \{0, 1, \dots, n_{\text{SRS}}^{\text{cs}, \text{max}}\}$, which are received from the eNodeB 105, are applied to the base sequence $\bar{r}_{u,v}$ as follows:

5 [0038]

The cyclic shift sequence $r_{u,v}^{(\alpha_{\tilde{p}})}(n)$ is defined by a cyclic shift $\alpha_{\tilde{p}}$ of a base sequence $\bar{r}_{u,v}(n)$ according to:

$$r_{u,v}^{(\alpha_{\tilde{p}})}(n) = e^{j\alpha_{\tilde{p}}n} \bar{r}_{u,v}(n), \quad 0 \leq n < M_{\text{sc}}^{\text{RS}}$$

[0039]

10 The cyclic shift $\alpha_{\tilde{p}}$ of the sounding reference signal is given as:

$$\alpha_{\tilde{p}} = 2\pi \frac{n_{\text{SRS}}^{\text{cs}, \tilde{p}}}{n_{\text{SRS}}^{\text{cs}, \text{max}}}$$

$$n_{\text{SRS}}^{\text{cs}, \tilde{p}} = \left(n_{\text{SRS}}^{\text{cs}} + \frac{n_{\text{SRS}}^{\text{cs}, \text{max}} \tilde{p}}{N_{\text{ap}}} \right) \bmod n_{\text{SRS}}^{\text{cs}, \text{max}},$$

$$\tilde{p} \in \{0, 1, \dots, N_{\text{ap}} - 1\}$$

where $n_{\text{SRS}}^{\text{cs}} \in \{0, 1, \dots, n_{\text{SRS}}^{\text{cs}, \text{max}}\}$ and N_{ap} is the number of antenna ports used for sounding reference signal transmission.

[0040]

15 For $n_{\text{SRS}}^{\text{cs}, \text{max}} = 48$, there are up to 48 orthogonal blocks.

[0041]

At step 215, the SRS sequence is constructed by concatenation of the cyclically shifted blocks. In particular, the blocks are concatenated according to an instruction received from the eNodeB 105.

20 [0042]

Advantageously, the method has Cubic Metric (CM), peak-to-power average ratio (PAPR), and cross-correlation properties, amongst overlapping SRS resources that are similar to in LTE.

[0043]

25 Fig. 3 illustrates an exemplary SRS sequence transmission diagram 300, according to an embodiment of the present invention.

[0044]

The sequence transmission diagram illustrates transmission from four UEs 305 (UE1,

UE2, UE3, UE4), each of which transmits an SRS sequence 310 comprising a plurality of cyclically shifted blocks 315 which are concatenated.

[0045]

Each of the blocks 315 are aligned in the frequency domain, and each block 315 is
5 orthogonal to the blocks 315 of the other UEs 305 at that frequency band.

[0046]

The base sequence and the cyclic shift used by each UE at each block is signalled by the eNodeB 105 to the UEs 120. As such, the eNodeB 105 is able to ensure, through appropriate scheduling of SRS resources, that mutual orthogonality is maintained between the SRS resources
10 of the different UEs. This is possible, as the same base sequence may be used by all UEs in a particular frequency band, but with a different cyclic shift.

[0047]

Advantageously, the methods and systems described above enable mutual orthogonality to be maintained between SRS resources of the different UEs, which in turn enables more
15 accurate uplink channel quality estimation. Furthermore, the method is aligned with existing LTE-based methods.

[0048]

In the present specification and claims (if any), the word 'comprising' and its derivatives including 'comprises' and 'comprise' include each of the stated integers but does not exclude the
20 inclusion of one or more further integers.

[0049]

Reference throughout this specification to 'one embodiment' or 'an embodiment' means that a particular feature, structure, or characteristic described in connection with the embodiment is included in at least one embodiment of the present invention. Thus, the appearance of the
25 phrases 'in one embodiment' or 'in an embodiment' in various places throughout this specification are not necessarily all referring to the same embodiment. Furthermore, the particular features, structures, or characteristics may be combined in any suitable manner in one or more combinations.

[0050]

30 In compliance with the statute, the invention has been described in language more or less specific to structural or methodical features. It is to be understood that the invention is not limited to specific features shown or described since the means herein described comprises preferred forms of putting the invention into effect. The invention is, therefore, claimed in any of its forms or modifications within the proper scope of the appended claims (if any)

appropriately interpreted by those skilled in the art.

[0051]

This application is based upon and claims the benefit of priority from Australian provisional patent application No. 2017902832, filed on July 19, 2017, the disclosure of which is
5 incorporated herein in its entirety by reference.

Reference Signs List

[0052]

	100	MU-MIMO system
10	105	eNodeB
	110, 125	antennas
	120	UE

CLAIMS

[Claim 1]

A method for transmitting sounding reference signals in a new radio (NR)

5 communications system including an eNodeB and a plurality of UEs, the method including:

generating, at a UE, a base sequence based upon a sequence number received from the eNodeB;

generating a plurality of blocks from the base sequence by applying cyclic-shifts to the base sequence on a plurality of subcarrier groups;

10 generating a sounding reference signal by concatenating the cyclically shifted blocks; and

transmitting the sounding reference signal to the eNodeB;

wherein the plurality of blocks comprises 48 orthogonal blocks, and each of the plurality of blocks is 4 Physical Resource Blocks (PRBs) long.

15 [Claim 2]

The method of Claim 1, wherein the base sequence $\bar{r}_{u,v}$ is determined according to:

$$\bar{r}_{u,v}(n) = x_q(n \bmod N_{\text{ZC}}^{\text{RS}}), \quad 0 \leq n < M_{\text{sc}}^{\text{RS}},$$

where the q^{th} root Zadoff-Chu sequence is defined by

$$x_q(m) = e^{-j \frac{\pi q m(m+1)}{N_{\text{ZC}}^{\text{RS}}}}, \quad 0 \leq m \leq N_{\text{ZC}}^{\text{RS}} - 1,$$

20 with q given by

$$q = \lfloor \bar{q} + 1/2 \rfloor + v \cdot (-1)^{\lfloor 2\bar{q} \rfloor}$$

$$\bar{q} = N_{\text{ZC}}^{\text{RS}} \cdot (u+1)/31,$$

where the length $N_{\text{ZC}}^{\text{RS}}$ of the Zadoff-Chu sequence is given by the largest prime number such that $N_{\text{ZC}}^{\text{RS}} < M_{\text{sc}}^{\text{RS}}$.

[Claim 3]

25 The method of Claim 1 or 2, wherein the cyclically-shifted base sequence $r_{u,v}^{(\alpha_{\bar{p}})}(n)$ is determined according to:

$$r_{u,v}^{(\alpha_{\bar{p}})}(n) = e^{j\alpha_{\bar{p}}n} \bar{r}_{u,v}(n), \quad 0 \leq n < M_{\text{sc}}^{\text{RS}},$$

where $\alpha_{\bar{p}}$ is the cyclic shift, and

wherein the cyclic shift $\alpha_{\tilde{p}}$ is determined according to:

$$\alpha_{\tilde{p}} = 2\pi \frac{n_{\text{SRS}}^{\text{cs}, \tilde{p}}}{n_{\text{SRS}}^{\text{cs}, \text{max}}}$$

$$n_{\text{SRS}}^{\text{cs}, \tilde{p}} = \left(n_{\text{SRS}}^{\text{cs}} + \frac{n_{\text{SRS}}^{\text{cs}, \text{max}} \tilde{p}}{N_{\text{ap}}} \right) \bmod n_{\text{SRS}}^{\text{cs}, \text{max}},$$

$$\tilde{p} \in \{0, 1, \dots, N_{\text{ap}} - 1\}$$

where $n_{\text{SRS}}^{\text{cs}} \in \{0, 1, \dots, n_{\text{SRS}}^{\text{cs}, \text{max}}\}$ and N_{ap} is the number of antenna ports used for sounding reference signal transmission.

5 [Claim 4]

The method of any one of Claims 1 to 3, wherein the sounding reference signal is transmitted such that blocks thereof are aligned with blocks of sounding reference signals of other UEs.

[Claim 5]

10 The method of any one of Claims 1 to 4, wherein the cyclic shift used by each UE at each block is signalled by the eNodeB to the UEs.

[Claim 6]

The method of any one of Claims 1 to 5, wherein different cyclic shifts are used by different UEs in corresponding blocks.

15 [Claim 7]

The method of any one of Claims 1 to 6, wherein the same base sequence is used by the UEs in corresponding blocks.

[Claim 8]

20 The method of any one of Claims 1 to 7, wherein the eNodeB is configured to schedule SRS resources at each of the UEs such that mutual orthogonality is maintained between the SRS resources of the different UEs.

[Claim 9]

A new radio communications system including an eNodeB and a plurality of UEs, wherein each UE is configured to:

25 generate, a base sequence based upon a sequence number received from the eNodeB;
generate a plurality of blocks from the base sequence by applying cyclic-shifts to the base sequence;

generate a sounding reference signal by concatenating the cyclically shifted blocks; and transmit to the sounding reference signal to the eNodeB.

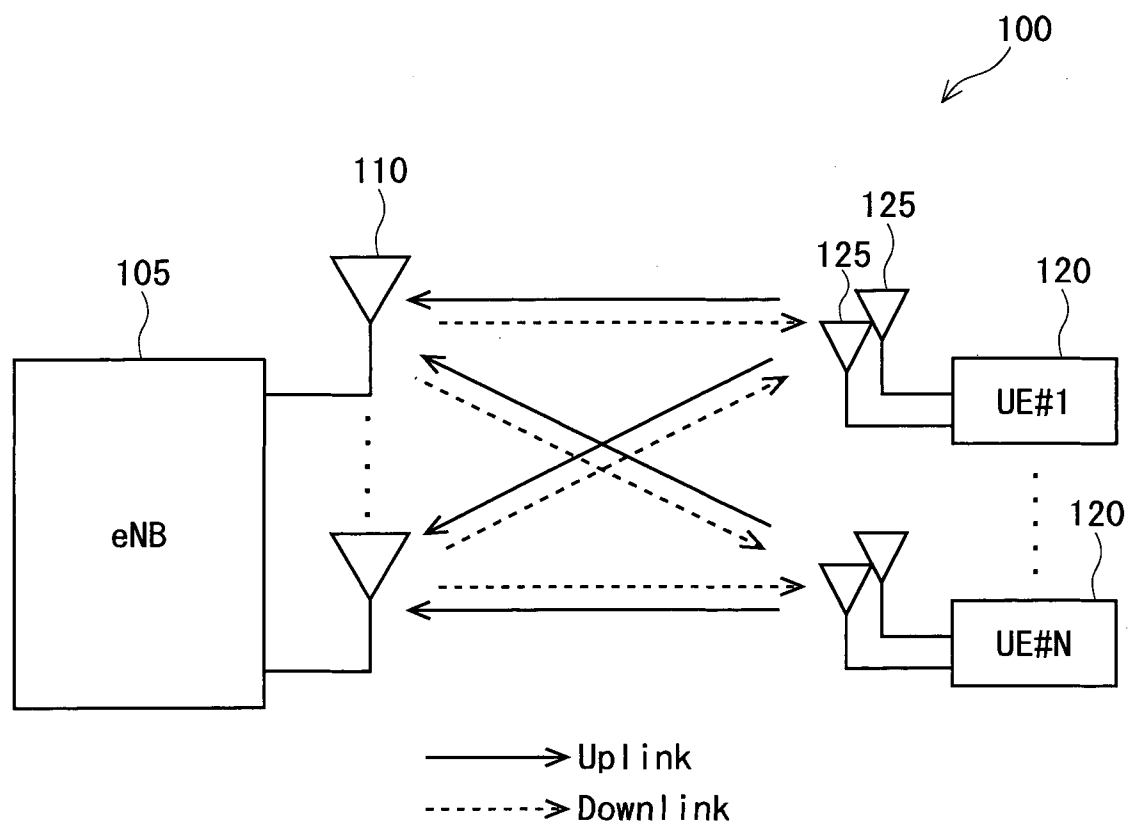


Fig. 1

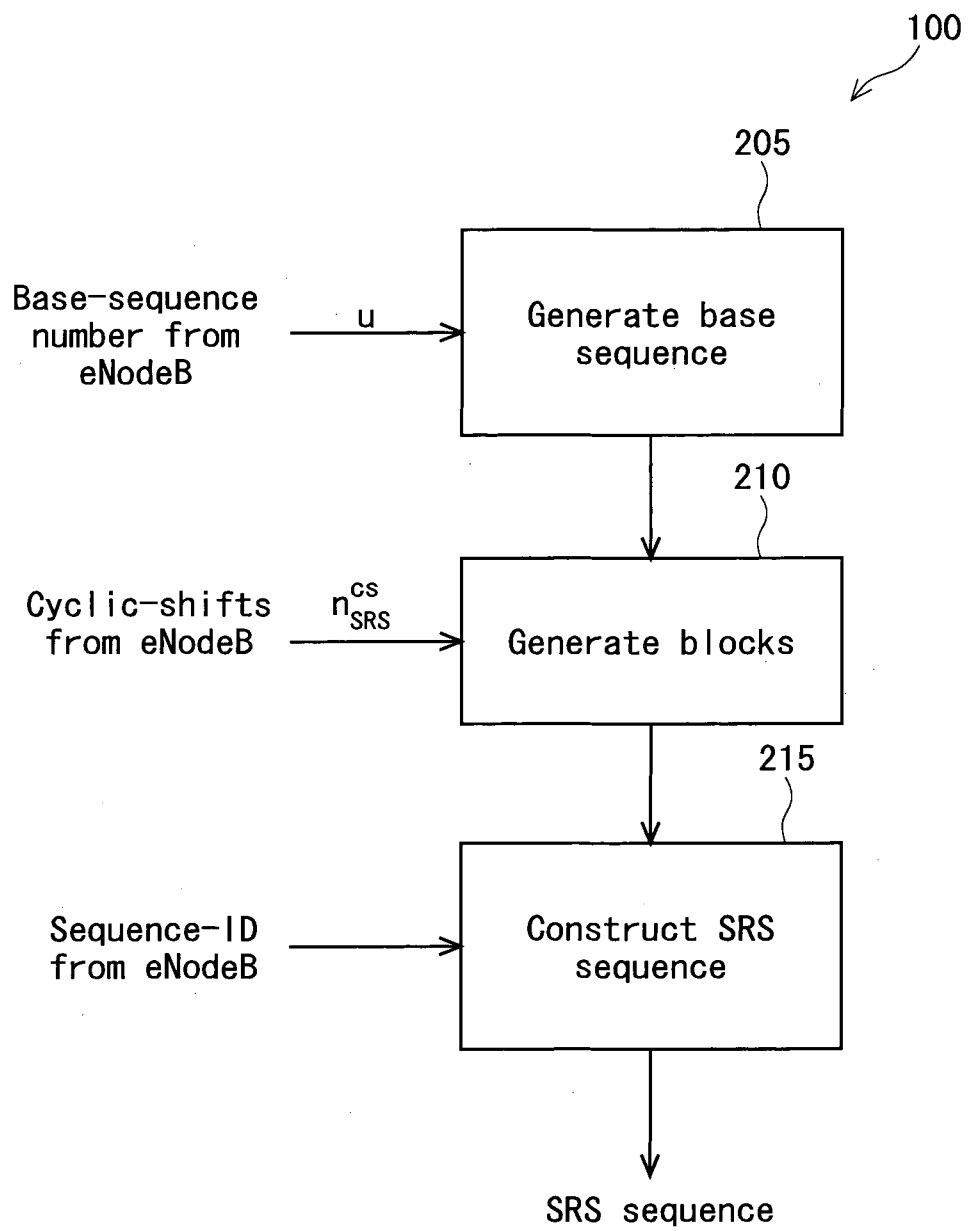


Fig. 2

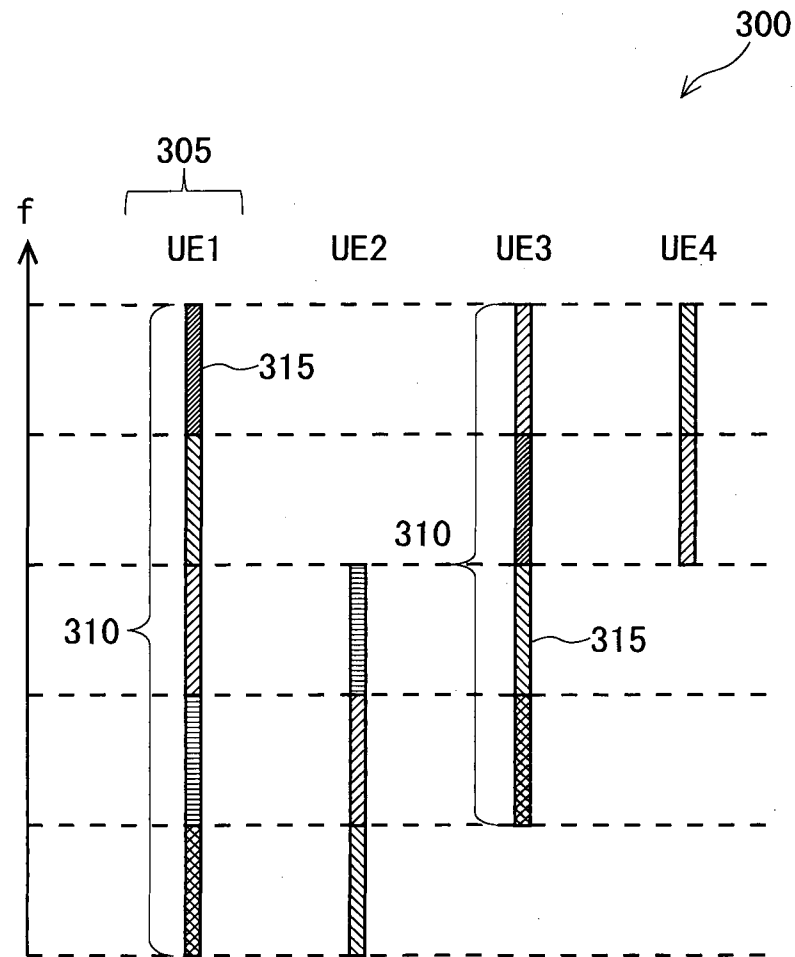


Fig. 3

INTERNATIONAL SEARCH REPORT

International application No
PCT/JP2018/009362

A. CLASSIFICATION OF SUBJECT MATTER

INV. H04J13/00 H04J13/10 H04L5/00 H04L27/26
ADD.

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)

H04J 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 practicable, 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	LG ELECTRONICS INTEL CORPORATION ZTE: "WF on SRS sequence generation for partial overlapping", 3GPP DRAFT; R1-1711767 WF ON SRS SEQUENCE GENERATION FOR PARTIAL OVERLAPPING, 3RD GENERATION PARTNERSHIP PROJECT (3GPP), MOBILE COMPETENCE CENTRE ; 650, ROUTE DES LUCIOLES ; F-06921 SOPHIA-ANTIPOLIS C , vol. RAN WG1, no. Qingdao, P.R. China; 20170627 - 20170630 29 June 2017 (2017-06-29), XP051306010, Retrieved from the Internet: URL: http://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_AH/NR_AH_1706/Docs/[retrieved on 2017-06-29] page 2 - page 3 ----- -/-	1-9



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

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Date of the actual completion of the international search

31 May 2018

Date of mailing of the international search report

11/06/2018

Name and mailing address of the ISA/

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INTERNATIONAL SEARCH REPORT

International application No

PCT/JP2018/009362

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	INTEL CORPORATION: "Discussion on SRS for NR", 3GPP DRAFT; R1-1710537, 3RD GENERATION PARTNERSHIP PROJECT (3GPP), MOBILE COMPETENCE CENTRE ; 650, ROUTE DES LUCIOLES ; F-06921 SOPHIA-ANTIPOLIS CEDEX ; FRANCE , vol. RAN WG1, no. Qingdao, China; 20170627 - 20170630 26 June 2017 (2017-06-26), XP051299744, Retrieved from the Internet: URL:http://www.3gpp.org/ftp/Meetings_3GPP_SYNC/RAN1/Docs/ [retrieved on 2017-06-26] Section 2.2; figure 2	1-9
X,P	----- NEC: "NR SRS Sequence Design", 3GPP DRAFT; R1-1712993, 3RD GENERATION PARTNERSHIP PROJECT (3GPP), MOBILE COMPETENCE CENTRE ; 650, ROUTE DES LUCIOLES ; F-06921 SOPHIA-ANTIPOLIS CEDEX ; FRANCE , vol. RAN WG1, no. Prague, Czech Republic; 20170821 - 20170825 20 August 2017 (2017-08-20), XP051315802, Retrieved from the Internet: URL:http://www.3gpp.org/ftp/Meetings_3GPP_SYNC/RAN1/Docs/ [retrieved on 2017-08-20] the whole document -----	1-9