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- (71) Applicant: **TELEFONAKTIEBOLAGET LM ERICSSON (PUBL)** [SE/SE]; S-164 83 Stockholm (SE).
- (72) Inventor; and
- (71) Applicant (for SC only): **ZHANG, Hao** [CN/CN]; Block A IP Building Guangzhou Info Port, No16 KeYun Road, Guangzhou, Guangdong 510665 (CN).
- (72) Inventors: **ÅHLANDER, Mats**; Evenemangsgatan 24, S-169 56 Solna (SE). **DALEVI, Mathias**; Warfvingesväg 18, 112 51 Stockholm (SE).
- (74) Agent: **CHINA SCIENCE PATENT & TRADEMARK AGENT LTD.**; Suite 4-312, No. 87 West 3rd Ring North Rd., Haidian District, Beijing 100089 (CN).
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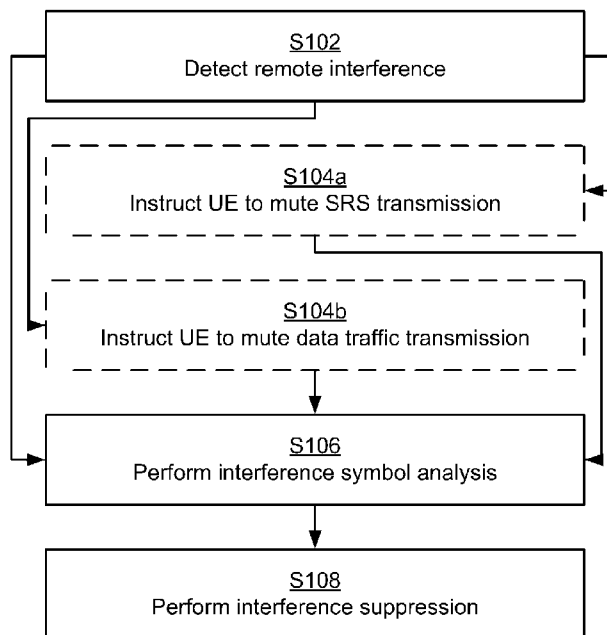


Fig. 3

(57) Abstract: There is provided techniques for interference suppression in a system operating according to a TDD pattern. A method is performed by a network node. The method comprises detecting remote interference. The remote interference is detected to impact an uplink slot in the TDD pattern. According to the TDD pattern, the uplink slot is preceded by a special slot. The method comprises performing interference symbol analysis. The interference symbol analysis is using at least one symbol located between a last occurring downlink symbol in the special slot and a first occurring DMRS symbol in the uplink slot. The method comprises performing interference suppression of the remote interference in accordance with the interference symbol analysis.



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INTERFERENCE IN A TDD OPERATING SYSTEM

TECHNICAL FIELD

Embodiments presented herein relate to a method, a network node, a computer program, and a computer program product for interference suppression in a system
5 operating according to a Time Division Duplex pattern.

BACKGROUND

In some (radio) access networks, especially those with Time Division Duplex (TDD) operation, remote interference (RI) negatively impacts the performance. This is because the same frequency spectrum is used for both the downlink (i.e., for
10 transmission from the network-side to the user -side) and the uplink (i.e., for transmission from the user-side to the network-side). RI, such as atmospheric duct interference from one or more remote cells, could impact both uplink traffic and antenna calibration performance. In **Fig. 1** is schematically illustrated a communication network 100 composed of transmission and reception points (TRPs)
15 110a, 110b, 110c, where each TRP 110a:110c is controlled by its own network node 200a, 200b, 200c to serve user equipment (UE), one of which is represented by UE 120. UE 120 is assumed to be served by network node 200a via TRP 110a. Each network node 200a:200c could be any of a radio access network node, radio base station, base transceiver station, node B (NB), evolved node B (eNB), gNB, access
20 point, integrated access and backhaul (IAB) node, or the like. Each UE 120 could be any of a portable wireless device, mobile station, mobile phone, handset, wireless local loop phone, smartphone, laptop computer, tablet computer, network equipped sensor device, Internet-of-Things (IoT) device, network equipped vehicle, or the like.

As schematically illustrated in Fig. 1, TRP 110a is assumed to be impacted by RI
25 caused by transmissions 140a, 140b from TRPs 110b and 110c. This could impact the transmission in the downlink 130a from TRP 110a towards UE 120 and/or the transmission in the uplink 130b from UE 120 towards TRP 110a. In this respect, TRP 11a might be distanced relatively far from TRPs 110b, 110c. The transmissions 140a, 140b could provide interfere in the guard period (GP) and uplink (UL) slots of the
30 communication between network node 200a and UE 120. Although illustrated as being reflected by an atmospheric duct layer 150, the RI could also arise from transmissions 140a, 140b from TRPs 110b and 110c as reflected from earth and

obstacles around TRP 110a. In this way, there could be multiple angles of arrival (AoA) for the transmissions 140a, 140b (that thus define RI signals). This could add to challenges of mitigate the RI for TRP 110a.

5 Additionally, there might be other sources of interference, such as cross-link interference which occurs when the transmission directions and the timing of neighboring cells in the network that are not aligned. Still further, cross-link interference might arise when different (semi-static) TDD patterns or dynamic TDD patterns are used by neighboring cells.

10 Techniques to detect and mitigate RI caused by atmospheric duct might utilize identity information embedded in the transmissions 140a, 140b. In this way, the location of the RI source (aggressor TRPs; in the present case defined by TRPs 110b, 110c) could be detected via the TRPs 110a:110c transmitting some special sequences which are received in the victim TRP (in the present case defined by TRP 110a). If RI is present, the identity information can be used to identify the aggressor TRPs. The
15 victim TRP could then request the aggressor TRPs to switch off some signals to reduce the RI caused at the victim TRP.

However, in case some signals are switched off for TRPs 110b, 110c, one drawback is that the traffic performance of the network nodes 200b, 200c (whose communication is based on TRPs 110b, 110c) would be impacted. In addition, it could be that the
20 network node 200a of the victim TRP and the network nodes 200b, 200c of the aggressor TRPs do not belong to the same network operator. This might make it difficult for network node 200a to request network node 200b and/or network node 200c to switch off some signals for TRP 110b and/or TRP 110c.

Hence, there is still a need for an efficient handling of RI at a victim TRP.

25 **SUMMARY**

An object of embodiments herein is to address the above issues.

A particular object is to provide handling of RI at a victim TRP without experiencing the above issues, or where the above issues at least are mitigated or reduced.

30 A particular object is to provide handling of RI at a victim TRP without impacting the traffic performance of other cells, or TRPs.

A particular object is to provide handling of RI at a victim TRP by means of interference suppression.

According to a first aspect there is presented a method for interference suppression in a system operating according to a TDD pattern. The method is performed by a network node. The method comprises detecting remote interference. The remote interference is detected to impact an uplink slot in the TDD pattern. According to the TDD pattern, the uplink slot is preceded by a special slot. The method comprises performing interference symbol analysis. The interference symbol analysis is using at least one symbol located between a last occurring downlink symbol in the special slot and a first occurring DMRS symbol in the uplink slot. The method comprises performing interference suppression of the remote interference in accordance with the interference symbol analysis.

According to a second aspect there is presented a network node for interference suppression in a system operating according to a TDD pattern. The network node comprises processing circuitry. The processing circuitry is configured to cause the network node to detect remote interference. The remote interference is detected to impact an uplink slot in the TDD pattern. According to the TDD pattern, the uplink slot is preceded by a special slot. The processing circuitry is configured to cause the network node to perform interference symbol analysis. The interference symbol analysis is using at least one symbol located between a last occurring downlink symbol in the special slot and a first occurring DMRS symbol in the uplink slot. The processing circuitry is configured to cause the network node to perform interference suppression of the remote interference in accordance with the interference symbol analysis.

According to a third aspect there is presented a network node for interference suppression in a system operating according to a TDD pattern. The network node comprises a detect module configured to detect remote interference. The remote interference is detected to impact an uplink slot in the TDD pattern. According to the TDD pattern, the uplink slot is preceded by a special slot. The network node comprises an analysis module configured to perform interference symbol analysis. The interference symbol analysis is using at least one symbol located between a last occurring downlink symbol in the special slot and a first occurring DMRS symbol in

the uplink slot. The network node comprises a suppression module configured to perform interference suppression of the remote interference in accordance with the interference symbol analysis.

5 According to a fourth aspect there is presented a computer program for interference suppression in a system operating according to a TDD pattern. The computer program comprises computer code which, when run on processing circuitry of a network node, causes the network node to perform actions. One action comprises the network node to detect remote interference. The remote interference is detected to impact an uplink slot in the TDD pattern. According to the TDD pattern, the uplink
10 slot is preceded by a special slot. One action comprises the network node to perform interference symbol analysis. The interference symbol analysis is using at least one symbol located between a last occurring downlink symbol in the special slot and a first occurring DMRS symbol in the uplink slot. One action comprises the network node to perform interference suppression of the remote interference in accordance
15 with the interference symbol analysis.

According to a fifth aspect there is presented a computer program product comprising a computer program according to the fourth aspect and a computer readable storage medium on which the computer program is stored. The computer readable storage medium could be a non-transitory computer readable storage
20 medium.

Advantageously, these aspects provide efficient handling of RI at a victim TRP without experiencing the above issue.

Advantageously, these aspects provide efficient handling of RI at a victim TRP without impacting the traffic performance of other cells, or TRPs.

25 Advantageously, these aspects provide efficient handling of RI at a victim TRP by means of interference suppression.

Advantageously, these aspects improve uplink key performance indicators.

Advantageously, these aspects can be used for interference suppression in the presence of RI in any symbols or any slots, e.g., guard periods, special slots, UL slot.

Other objectives, features and advantages of the enclosed embodiments will be apparent from the following detailed disclosure, from the attached dependent claims as well as from the drawings.

Generally, all terms used in the claims are to be interpreted according to their
5 ordinary meaning in the technical field, unless explicitly defined otherwise herein. All references to "a/an/the element, apparatus, component, means, module, step, etc." are to be interpreted openly as referring to at least one instance of the element, apparatus, component, means, module, step, etc., unless explicitly stated otherwise. The steps of any method disclosed herein do not have to be performed in the exact
10 order disclosed, unless explicitly stated.

BRIEF DESCRIPTION OF THE DRAWINGS

The inventive concept is now described, by way of example, with reference to the accompanying drawings, in which:

Fig. 1 is a schematic diagram illustrating a communication network according to
15 embodiments;

Fig. 2 schematically illustrates how RI impacts different signals in a special slot and an UL slot in a TDD frame structure according to an example;

Fig. 3 is a flowchart of methods according to embodiments;

Fig. 4 shows a comparison between a spatial domain analysis of a received signal
20 according to an embodiment;

Fig. 5 schematically illustrates examples of blanked symbols in TDD frame structures according to an embodiment;

Fig. 6 is a flowchart of a method according to an embodiment;

Fig. 7 is a schematic diagram showing functional units of a network node according to
25 an embodiment;

Fig. 8 is a schematic diagram showing functional modules of a network node according to an embodiment; and

Fig. 9 shows one example of a computer program product comprising computer readable storage medium according to an embodiment.

DETAILED DESCRIPTION

The inventive concept will now be described more fully hereinafter with reference to the accompanying drawings, in which certain embodiments of the inventive concept are shown. This inventive concept may, however, be embodied in many different forms and should not be construed as limited to the embodiments set forth herein; rather, these embodiments are provided by way of example so that this disclosure will be thorough and complete, and will fully convey the scope of the inventive concept to those skilled in the art. Like numbers refer to like elements throughout the description. Any step or feature illustrated by dashed lines should be regarded as optional.

As noted above, there is still a need for an efficient handling of RI at a victim TRP.

As further noted above, a particular object is to provide handling of RI at a victim TRP by means of interference suppression. Further in this respect, interference suppression is based on measurements on the DMRSs as is located in symbol 3 and symbol 10 in each UL slot. However, it is possible that the RI only impacts symbols 0, 1, and 2 in the UL slot, or that the impact is lower in symbol 3 than in symbols 0, 1, or 2. This is schematically illustrated in Fig. 2. **Fig. 2** is illustrating signals in a special slot and an UL slot in a TDD frame structure 160, together with RI. The illustrated part of the special slot is composed of symbols assigned for downlink (DL), guard symbols, antenna calibration (AC), and sounding reference signals (SRSs). The uplink (UL) slot is composed of symbols assigned to a physical uplink channel (PUSCH) and DMRS. It can be seen that while the RI impacts the DMRS in symbol 3 of the UL slot, the RI does not impact the DMRS in symbol 10. Further, as schematically illustrated, the impact of the RI is higher in symbols 0, 1, 2, 3 of the UL slot (as well as in symbols 11, 12, 13 of the special slot) than in symbol 3 of the UL slot. In such a case, measurements based on the DMRSs might be of little use when seeking to mitigate the RI issue for the UL symbols 0, 1, and 2.

The embodiments disclosed herein therefore relate to techniques for interference suppression in a system operating according to a TDD pattern. In order to obtain

such techniques, there is provided a network node 200a, a method performed by the network node 200a, a computer program product comprising code, for example in the form of a computer program, that when run on a network node 200a, causes the network node 200a to perform the method.

- 5 **Fig. 3** is a flowchart illustrating embodiments of methods for interference suppression in a system operating according to a TDD pattern. The methods are performed by the network node 200a. The methods are advantageously provided as computer programs 920.

10 S102: The network node 200a detects RI. The RI is detected to impact an UL slot in the TDD pattern. According to the TDD pattern, the UL slot is preceded by a special slot.

The interference symbol analysis is performed using a symbol located between the last downlink symbol in a special slot and the first DMRS symbol in the next UL slot.

15 S106: The network node 200a performs interference symbol analysis. The interference symbol analysis is using at least one symbol located between a last occurring downlink symbol in the special slot and a first occurring DMRS symbol in the UL slot.

20 In some examples, the at least one symbol located between the last occurring downlink symbol in the special slot and the first occurring DMRS symbol in the UL slot is denoted an analysis symbol.

S108: The network node 200a performs interference suppression of the RI in accordance with the interference symbol analysis.

25 Embodiments relating to further details of interference suppression in a system operating according to a TDD pattern as performed by the network node 200a will now be disclosed with continued reference to Fig. 3.

Further aspects of detecting the RI as in S102 will be disclosed next.

There could be different ways in which the RI is detected in S102. For example, spatial analysis can be used to detect whether RI is present or not. Let the N -valued

received signal at TRP 110 be denoted Y_{UL} , where N is the number of antennas at TRP 110a. That is:

$$Y_{UL} = [Y_{UL}(1), Y_{UL}(2), \dots, Y_{UL}(N)]$$

In general terms, Y_{UL} has two parts; a received known signal, denoted Y_{AC} , and RI signals, denoted Y_{RI} . In this respect, there could be different examples of known
 5 signal. In one example the antenna calibration (AC) signal symbol as collected in the guard period can be utilized to detect the RI. That is, in some embodiments, the RI is detected by analyzing a received signal in a symbol in the special slot dedicated for an antenna calibration signal. The antenna calibration signal might be transmitted by
 the network node 200a via an internal coupling network in the network node 200a
 10 (or TRP 110a). The received signal might then be composed of the RI and the antenna calibration signal. That is:

$$Y_{UL} = Y_{AC} + Y_{RI}$$

A spatial-domain Fourier transform (SDFT) conversion matrix C can then be constructed as follows.

Define a horizontal matrix R_K with K columns (corresponding to the number of
 15 columns in the antenna at TRP 110a):

$$R_K = 1/\sqrt{K} \begin{bmatrix} 1 & 1 & \dots & 1 \\ e^{-m_0} & e^{-m_1} & \dots & e^{-m_{K-1}} \\ \vdots & \vdots & \ddots & \vdots \\ e^{-(K-1)m_0} & e^{-(K-1)m_1} & \dots & e^{-(K-1)m_{K-1}} \end{bmatrix}, m_l = \frac{j2\pi l}{K}$$

Define a vertical matrix R_V with V rows (corresponding to the number of rows in the antenna at TRP 110a):

$$R_V = 1/\sqrt{V} \begin{bmatrix} 1 & 1 & \dots & 1 \\ e^{-n_0} & e^{-n_1} & \dots & e^{-n_{V-1}} \\ \vdots & \vdots & \ddots & \vdots \\ e^{-(V-1)n_0} & e^{-(V-1)n_1} & \dots & e^{-(V-1)n_{V-1}} \end{bmatrix}, n_l = \frac{j2\pi l}{V}$$

Define a polarization matrix R_P :

$$R_P = \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix}$$

The conversion matrix C is then the Kronecker product of R_P , R_K and R_V :

$$C = R_P \otimes R_K \otimes R_V$$

With the conversion matrix C the received signal Y_{UL} in the antenna space can be converted to $Y'_{UL} = [Y'_{UL}(1), Y'_{UL}(2), \dots, Y'_{UL}(M)]$ in the spatial domain or beam space, where M is the number of beams in the spatial domain, as follows:

$$Y'_{UL} = CY_{UL}$$

5 Intermediate reference is here made to **Fig. 4** in which is shown a comparison between a spatial domain analysis of a received signal with RI and an AC signal (Fig. 4(a)) and with the same received signal where the AC signal having been removed (Fig. 4(b)). For the AC signal to be removed it is assumed that the symbol in which the AC signal is transmitted is known. During runtime, the AC signal is assumed to be
 10 transmitted in a beam with a certain beam index, hereinafter denoted a . Then the AC signal can be removed to yield Y''_{UL} as follows:

$$Y''_{UL} = Y'_{UL} - Y'_{UL}(a)$$

Hence, in some embodiments, detecting the RI involves removing any contribution of the antenna calibration signal from the received signal after having converted the received signal from antenna space to beam space.

15 In other embodiments, the antenna calibration signal is muted such that the received signal is without any contribution of the antenna calibration signal. That is, the AC signal can be muted such that only RI is received. In this way, $Y''_{UL} = Y'_{UL}$. The above procedure applies also other known signals than the AC signal.

The power P of the received signal in other beams can then be used to determine if RI
 20 is present or not.

$$P = \sum Y''_{UL}(b) \quad b = 1, 2, \dots, N$$

Here, b does not include the beam index a . For example, RI can be determined as present in case $P > \theta$, where θ is some threshold value.

The RI impact to actual antenna calibration can be mitigated by many techniques, e.g., time domain filtering. In this way it can be assumed that the TRP 110a is calibrated during the process for detecting the RI and that beam domain analysis can be performed based on this assumption.

- 5 The symbols in which the antenna calibration signal is transmitted might be monitored during several special slots (and hence over some TDD frames) to determine if RI is present or not. Therefore, in some embodiments, detecting the RI involves monitoring the symbol in the special slot dedicated for the antenna calibration signal during a period of at least two frames, where the RI is detected only
10 when the RI persists during this period of at least two frames.

Aspects of selecting the analysis symbol and how different examples of the analysis symbol might impact the interference suppression will be disclosed next.

- In some non-limiting examples, the analysis symbol is a symbol in the special slot dedicated for an antenna calibration signal. Hence, in some embodiments, the
15 analysis symbol is the symbol in the special slot dedicated for the antenna calibration signal, and any contribution of the antenna calibration signal has been removed from the analysis symbol when the interference symbol analysis is performed. The signal Y''_{UL} could then be converted to an antenna domain signal \tilde{Y}_{RI} :

$$\tilde{Y}_{RI} = C^{-1}Y''_{UL}$$

\tilde{Y}_{RI} is thus the RI signal in antenna domain with the AC signal removed.

- 20 In some non-limiting examples, the analysis symbol is a symbol in the special slot dedicated for a sounding reference signal (SRS). Then, one of the symbols dedicated for the SRS signal might be blanked. This can be achieved by instructing the UE 120 to mute the SRS transmission in this symbol.

- Hence, in some embodiments, the analysis symbol is the symbol in the special slot
25 dedicated for the SRS signal, and the network node 200a is configured to perform (optional) step S104a:

S104a: The network node 200a instructs user equipment 120 served by the network node 200a to mute SRS transmission in the analysis symbol.

With intermediate reference to Fig. 2, this implies that the user equipment 120 is instructed to mute transmission on symbol 12 or 13 of the special slot.

In some non-limiting examples, the analysis symbol is a symbol in the UL slot dedicated for data traffic. Then, one of the symbols dedicated for UL data traffic
5 might be blanked. This can be achieved by instructing the UE 120 to mute the UL data traffic transmission in this symbol. Hence, in some embodiments, the analysis symbol is the symbol in the UL slot dedicated for the data traffic, and the network node 200a is configured to perform (optional) step S104b:

S104b: The network node 200a instructs user equipment 120 served by the network
10 node 200a to mute data traffic transmission in the analysis symbol.

With intermediate reference to Fig. 2, this implies that the user equipment 120 is instructed to mute transmission on symbol 0, 1 or 2 of the UL slot. In **Fig. 5** it is illustrating four different examples of blanked symbols in a special slot or an UL slot in TDD frame structures 500a, 500b, 500c, 500d. In general terms, the TDD frame
15 structures 500a, 500b, 500c, 500d are otherwise the same as the TDD frame structure 160 illustrated in Fig. 2, although the different allocations of signals to the symbols are not explicitly indicated in Fig. 5. That is, symbols 6, 7, 8 in the special slot are DL symbols, as in Fig. 2, and so on,

Further aspects of performing the interference symbol analysis in S106 and the
20 interference suppression of the RI in S108 will be disclosed next.

In some aspects, the interference symbol analysis involves calculating a covariance matrix Q (using the processed AC symbol, the blanked SRS symbol, or the blanked traffic symbol). That is, in some embodiments, performing the interference symbol analysis involves calculating a covariance matrix based on the analysis symbol.

25 This covariance matrix can then be used during the interference suppression of the RI in S108. In this respect, there could be different ways to perform the interference suppression. In some aspects, the interference suppression involves interference rejection combining. Therefore, in some embodiments, performing the interference suppression involves performing interference rejection combining in accordance with
30 the calculated covariance matrix.

In general terms, UL interference rejection combining can be used for mitigating UL interference. UL interference rejection combining works by projecting the inverse of a covariance matrix Q onto the received base band signal. As the atmospheric duct interference from a downlink carrier in one cell is visible as interference on an UL carrier in another cell an UL interference rejection combining algorithm should be able to mitigate this interference in the same was as UL interference.

The covariance matrix Q is typically computed using one or more DMRS symbol, e.g., in UL symbols 3 and 10. This implies that the UL interference must overlap the first DMRS symbol, e.g., symbol 3, for the UL interference rejection combining to take effect. If the UL interference caused by the atmospheric duct interference would overlap any of the UL symbols 0 to 2 but not the DMRS in symbol 3, this would imply that the UL interference rejection combining would not take effect. As symbols 0 to 2 could be severely interfered by RI this could cause significant performance degradation of the interference rejection combining if not handled properly. One way to address this is to adapt the interference rejection combining by adapting the calculation of the covariance matrix as herein disclosed, namely that the covariance matrix is calculated (at least) based on the analysis symbol. That is, instead of adding a third DMRS symbol at symbol 0 or 1 in the UL slot, the network node 200a might configure a blank symbol, without any data, at symbol 0 or 1 in the UL slot, or in symbol 12 or 13 in special slot. This can be achieved by the above-disclosed blanking. In some examples, the covariance matrix Q is calculated as follows:

$$Q = E(Y_{blank}Y_{blank}^H)$$

Here, Y_{blank} is the blanked SRS symbol or data traffic symbol. One alternative is to use the processed AC symbol to compute the covariance matrix. That is:

$$Q = E(\tilde{Y}_{RI}\tilde{Y}_{RI}^H)$$

In some examples, the interference rejection combining is based on averaging of covariance matrices from multiple symbols. That is, in some embodiments, the interference rejection combining is based on at least two covariance matrices, where each of the at least two covariance matrices is calculated based on a respective symbol located between the last occurring downlink symbol in the special slot and the first

occurring DMRS symbol in the UL slot. According to some non-limiting examples, this averaging can be achieved as follows:

$$Q_{avg} = \frac{1}{N_Q} \sum_{i=1}^{N_Q} Q_i$$

Q_{avg} is the averaged covariance matrix and N_Q is the number of covariance matrices used in the averaging.

- 5 In some examples, the covariance matrix is computed using any combination of symbols with blanked symbol, DMRS symbol 3 and 10. Hence, in some embodiments, the interference rejection combining is based on the at least two covariance matrices and a third covariance matrix, and the third covariance matrix is calculated based on the first occurring DMRS symbol in the UL slot or a second occurring DMRS symbol
10 in the UL slot.

Further aspects of selecting which of the processed AC symbol, the blanked SRS symbol, or the blanked traffic symbol to use in the interference symbol analysis, for example when computing the covariance matrix Q , will be disclosed next.

- In some aspects, the analysis symbol is selected as the at least one symbol located
15 between a last occurring downlink symbol in the special slot and the first occurring DMRS symbol in the UL slot for which an UL key performance indicator (KPI) is highest. This at least one symbol is then used when performing the interference symbol analysis and/or when performing interference suppression. In this way, and as will be further disclosed below with reference to Fig. 6, which symbol to use as
20 analysis symbol can be iteratively determined to achieve the highest level of interference suppression (or conversely, the highest UL KPI). In this respect, there might be different examples of UL KPIs. In some non-limiting examples, the UL KPI is based on any, or any combination, of: number of acknowledgements (ACKs), number of negative acknowledgements (NACKs), block error rate (BLER), traffic
25 throughput.

In some aspects, the analysis symbol is selected as the at least one symbol located between a last occurring downlink symbol in the special slot and the first occurring DMRS symbol in the UL slot for which estimated received power of the RI is highest.

This at least one symbol is then used when performing the interference symbol analysis and/or when performing interference suppression. This might involve estimating the slope of the RI, that is, how the RI varies over time.

5 the at least one symbol located between a last occurring downlink symbol in the special slot and the first occurring DMRS symbol in the UL slot for which estimated received power of the RI is highest is used when performing the interference symbol analysis and/or when performing interference suppression.

One example method for interference suppression in a system operating according to a TDD pattern based on at least some of the above disclosed embodiments as
10 performed by the network node 200a will be disclosed net with reference to the flowchart of **Fig. 6**.

S201. Detect RI from AC Signal in Beam Domain: Network node 200a performs monitoring of RI by analyzing a received signal in a symbol in the special slot dedicated for an antenna calibration signal.

15 S202. RI present?: Network node 200a checks whether RI is present or not. If present, S203 is entered. If not present, S102 can be entered again, possibly after some time delay.

S203. Operation Selection using UL KPI Comparison: Network node 200a selects based on which type of analysis symbol the interference symbol analysis is to be
20 performed. Depending on the selection, one of S204a, S204b, S204c is entered.

S204a. Get RI signal by processing AC Signal with AC removed: The analysis symbol is the symbol in the special slot dedicated for the antenna calibration signal Network node 200a performs the interference symbol analysis after any contribution of the antenna calibration signal has been removed from the analysis symbol.

25 S204b. Blank one of the SRS symbols: The analysis symbol is a symbol in the special slot dedicated for an SRS signal. Network node 200a performs the interference symbol analysis after having instructed UEs 120 served by network node 200a to mute SRS transmission in the analysis symbol.

S204c. Blank one of the UL traffic symbols: The analysis symbol is a symbol in the special slot dedicated for data traffic. Network node 200a performs the interference symbol analysis after having instructed UEs 120 served by network node 200a to mute data traffic transmission in the analysis symbol.

- 5 S205. IRC with Processed and/or Blanked Symbol(s): Network node 200a performs the interference suppression of the RI in accordance with the interference symbol analysis.

S206. UL KPI Measurement: Network node 200a estimates the UL KPI for performing the interference suppression using the type of analysis symbol selected in
10 S203. The UL KPI can be stored and/or compared to the UL KPI resulting from one or more previous occurrences of the interference suppression. In this way, network node 200a could, over time, have access to a bank of UL KPIs for different types of analysis symbols. Another type of analysis symbol can then be selected in S203 in case the UL KPI (as estimated for the same selected type of analysis symbol) has
15 decreased, etc. Likewise, in case the UL KPI is above some threshold value for one or more consecutive applications of the interference suppression, the same type of analysis symbol can be continued to be used also for further applications of the interference suppression for a certain period.

Fig. 7 schematically illustrates, in terms of a number of functional units, the
20 components of a network node 200a according to an embodiment. Processing circuitry 210 is provided using any combination of one or more of a suitable central processing unit (CPU), multiprocessor, microcontroller, digital signal processor (DSP), etc., capable of executing software instructions stored in a computer program product 910 (as in Fig. 9), e.g. in the form of a storage medium 230. The processing
25 circuitry 210 may further be provided as at least one application specific integrated circuit (ASIC), or field programmable gate array (FPGA).

Particularly, the processing circuitry 210 is configured to cause the network node 200a to perform a set of operations, or steps, as disclosed above. For example, the storage medium 230 may store the set of operations, and the processing circuitry 210
30 may be configured to retrieve the set of operations from the storage medium 230 to cause the network node 200a to perform the set of operations. The set of operations may be provided as a set of executable instructions.

Thus the processing circuitry 210 is thereby arranged to execute methods as herein disclosed. The storage medium 230 may also comprise persistent storage, which, for example, can be any single one or combination of magnetic memory, optical memory, solid state memory or even remotely mounted memory. The network node 200a may
5 further comprise a communications (comm.) interface 220 at least configured for communications with other functions, nodes, entities, and devices. As such the communications interface 220 may comprise one or more transmitters and receivers, comprising analogue and digital components. The processing circuitry 210 controls the general operation of the network node 200a e.g. by sending data and control
10 signals to the communications interface 220 and the storage medium 230, by receiving data and reports from the communications interface 220, and by retrieving data and instructions from the storage medium 230. Other components, as well as the related functionality, of the network node 200a are omitted in order not to obscure the concepts presented herein.

15 **Fig. 8** schematically illustrates, in terms of a number of functional modules, the components of a network node 200a according to an embodiment. The network node 200a of Fig. 8 comprises a number of functional modules; a detect module 210a configured to perform step S102, an analysis module 210d configured to perform step S106, and a suppression (supp.) module 210e configured to perform step S108. The
20 network node 200a of Fig. 8 may further comprise a number of optional functional modules, such as any of a (first) instruct module 210b configured to perform step S104a and a (second) instruct module 210c configured to perform step S104b. In general terms, each functional module 210a:210e may in one embodiment be implemented only in hardware and in another embodiment with the help of software,
25 i.e., the latter embodiment having computer program instructions stored on the storage medium 230 which when run on the processing circuitry makes the network node 200a perform the corresponding steps mentioned above in conjunction with Fig 8. It should also be mentioned that even though the modules correspond to parts of a computer program, they do not need to be separate modules therein, but the way in
30 which they are implemented in software is dependent on the programming language used. Preferably, one or more or all functional modules 210a:210e may be implemented by the processing circuitry 210, possibly in cooperation with the communications interface 220 and/or the storage medium 230. The processing

circuitry 210 may thus be configured to from the storage medium 230 fetch instructions as provided by a functional module 210a:210e and to execute these instructions, thereby performing any steps as disclosed herein.

The network node 200a may be provided as a standalone device or as a part of at least one further device. For example, the network node 200a may be provided in a node of the radio access network or in a node of the core network. Alternatively, functionality of the network node 200a may be distributed between at least two devices, or nodes. These at least two nodes, or devices, may either be part of the same network part (such as the radio access network or the core network) or may be spread between at least two such network parts. In general terms, instructions that are required to be performed in real time may be performed in a device, or node, operatively closer to the cell than instructions that are not required to be performed in real time. Thus, a first portion of the instructions performed by the network node 200a may be executed in a first device, and a second portion of the of the instructions performed by the network node 200a may be executed in a second device; the herein disclosed embodiments are not limited to any particular number of devices on which the instructions performed by the network node 200a may be executed. Hence, the methods according to the herein disclosed embodiments are suitable to be performed by a network node 200a residing in a cloud computational environment. Therefore, although a single processing circuitry 210 is illustrated in Fig. 7 the processing circuitry 210 may be distributed among a plurality of devices, or nodes. The same applies to the functional modules 210a:210e of Fig. 8 and the computer program 920 of Fig. 9.

Some (radio) access network architectures define network nodes (or gNBs) comprising multiple component parts or nodes: a central unit (CU), one or more distributed units (DUs), and one or more radio units (RUs). The protocol layer stack of the network node is divided between the CU, the DUs and the RUs, with one or more lower layers of the stack implemented in the RUs, and one or more higher layers of the stack implemented in the CU and/or DUs. The CU is coupled to the DUs via a fronthaul higher layer split (HLS) network; the CU/DUs are connected to the RUs via a fronthaul lower-layer split (LLS) network. The DU may be combined with the CU in some embodiments, where a combined DU/CU may be referred to as a CU or simply a baseband unit. A communication link for communication of user data

messages or packets between the RU and the baseband unit, CU, or DU is referred to as a fronthaul network or interface. Messages or packets may be transmitted from the network node 200 in the downlink (i.e., from the CU to the RU) or received by the network node 200 in the uplink (i.e., from the RU to the CU).

5 **Fig. 9** shows one example of a computer program product 910 comprising computer readable storage medium 930. On this computer readable storage medium 930, a computer program 920 can be stored, which computer program 920 can cause the processing circuitry 210 and thereto operatively coupled entities and devices, such as the communications interface 220 and the storage medium 230, to execute methods
10 according to embodiments described herein. The computer program 920 and/or computer program product 910 may thus provide means for performing any steps as herein disclosed.

In the example of Fig. 9, the computer program product 910 is illustrated as an optical disc, such as a CD (compact disc) or a DVD (digital versatile disc) or a Blu-Ray
15 disc. The computer program product 910 could also be embodied as a memory, such as a random access memory (RAM), a read-only memory (ROM), an erasable programmable read-only memory (EPROM), or an electrically erasable programmable read-only memory (EEPROM) and more particularly as a non-volatile storage medium of a device in an external memory such as a USB (Universal Serial
20 Bus) memory or a Flash memory, such as a compact Flash memory. Thus, while the computer program 920 is here schematically shown as a track on the depicted optical disk, the computer program 920 can be stored in any way which is suitable for the computer program product 910.

The inventive concept has mainly been described above with reference to a few
25 embodiments. However, as is readily appreciated by a person skilled in the art, other embodiments than the ones disclosed above are equally possible within the scope of the inventive concept, as defined by the appended patent claims.

CLAIMS

1. A method for interference suppression in a system operating according to a Time Division Duplex, TDD, pattern, wherein the method is performed by a network node (200a), and wherein the method comprises:
 - 5 detecting (S102) remote interference, wherein the remote interference is detected to impact an uplink slot in the TDD pattern, and wherein, according to the TDD pattern, the uplink slot is preceded by a special slot;
 - performing (S106) interference symbol analysis, wherein the interference symbol analysis is using at least one symbol located between a last occurring
10 downlink symbol in the special slot and a first occurring demodulation reference signal, DMRS, symbol in the uplink slot; and
 - performing (S108) interference suppression of the remote interference in accordance with the interference symbol analysis.
 2. The method according to claim 1, wherein the remote interference is detected by
15 analyzing a received signal in a symbol in the special slot dedicated for an antenna calibration signal.
 3. The method according to claim 2, wherein the received signal is composed of the remote interference and the antenna calibration signal.
 4. The method according to claim 2 or 3, wherein the antenna calibration signal is
20 transmitted by the network node (200a) via an internal coupling network in the network node (200a).
 5. The method according to claim 4, wherein detecting the remote interference involves removing any contribution of the antenna calibration signal from the received signal after having converted the received signal from antenna space to
25 beam space.
 6. The method according to claim 2, wherein the antenna calibration signal is muted such that the received signal is without any contribution of the antenna calibration signal.

7. The method according to any preceding claim, wherein detecting the remote interference involves monitoring the symbol in the special slot dedicated for the antenna calibration signal during a period of at least two frames, and wherein the remote interference is detected only when the remote interference persists during
5 said period of at least two frames.
8. The method according to any preceding claim, wherein the at least one symbol located between the last occurring downlink symbol in the special slot and the first occurring DMRS symbol in the uplink slot is denoted an analysis symbol, and wherein the analysis symbol is any of:
- 10
- a symbol in the special slot dedicated for an antenna calibration signal,
 - a symbol in the special slot dedicated for a sounding reference signal, SRS,
 - a symbol in the uplink slot dedicated for data traffic.
9. The method according to claim 8, wherein the analysis symbol is the symbol in the special slot dedicated for the antenna calibration signal, and wherein any
15 contribution of the antenna calibration signal has been removed from the analysis symbol when performing the interference symbol analysis.
10. The method according to claim 8, wherein the analysis symbol is the symbol in the special slot dedicated for the SRS signal, and wherein the method further comprises:
- 20
- instructing (S104a) user equipment (120) served by the network node (200a) to mute SRS transmission in the analysis symbol.
11. The method according to claim 8, wherein the analysis symbol is the symbol in the uplink slot dedicated for the data traffic, and wherein the method further comprises:
- 25
- instructing (S104b) user equipment (120) served by the network node (200a) to mute data traffic transmission in the analysis symbol.
12. The method according to any preceding claim, wherein performing the interference symbol analysis involves calculating a covariance matrix based on the at

least one symbol located between the last occurring downlink symbol in the special slot and the first occurring DMRS symbol in the uplink slot.

13. The method according to claim 12, wherein performing the interference suppression involves performing interference rejection combining in accordance with
5 the calculated covariance matrix.
14. The method according to claim 13, wherein the interference rejection combining is based on at least two covariance matrices, and wherein each of the at least two covariance matrices is calculated based on a respective symbol located between the
10 last occurring downlink symbol in the special slot and the first occurring DMRS symbol in the uplink slot.
15. The method according to claim 14, wherein the interference rejection combining is based on the at least two covariance matrices and a third covariance matrix, and wherein the third covariance matrix is calculated based on the first occurring DMRS symbol in the uplink slot or a second occurring DMRS symbol in the uplink slot.
- 15 16. The method according to any preceding claim, wherein the at least one symbol located between a last occurring downlink symbol in the special slot and the first occurring DMRS symbol in the uplink slot for which an uplink key performance indicator, KPI, is highest is used when performing the interference symbol analysis and/or when performing interference suppression.
- 20 17. The method according to claim 16, wherein the uplink KPI is based on any, or any combination, of: number of acknowledgements, ACKs, number of negative acknowledgements, NACKs, block error rate, BLER, traffic throughput.
18. The method according to any preceding claim, wherein the at least one symbol located between a last occurring downlink symbol in the special slot and the first
25 occurring DMRS symbol in the uplink slot for which estimated received power of the remote interference is highest is used when performing the interference symbol analysis and/or when performing interference suppression.
19. A network node (200a) for interference suppression in a system operating according to a Time Division Duplex, TDD, pattern, the network node (200a)

comprising processing circuitry (210), the processing circuitry being configured to cause the network node (200a) to:

5 detect remote interference, wherein the remote interference is detected to impact an uplink slot in the TDD pattern, and wherein, according to the TDD pattern, the uplink slot is preceded by a special slot;

perform interference symbol analysis, wherein the interference symbol analysis is using at least one symbol located between a last occurring downlink symbol in the special slot and a first occurring demodulation reference signal, DMRS, symbol in the uplink slot; and

10 perform interference suppression of the remote interference in accordance with the interference symbol analysis.

20. A network node (200a) for interference suppression in a system operating according to a Time Division Duplex, TDD, pattern, the network node (200a) comprising:

15 a detect module (210a) configured to detect remote interference, wherein the remote interference is detected to impact an uplink slot in the TDD pattern, and wherein, according to the TDD pattern, the uplink slot is preceded by a special slot;

an analysis module (210d) configured to perform interference symbol analysis, wherein the interference symbol analysis is using at least one symbol located between
20 a last occurring downlink symbol in the special slot and a first occurring demodulation reference signal, DMRS, symbol in the uplink slot; and

a suppression module (210e) configured to perform interference suppression of the remote interference in accordance with the interference symbol analysis.

21. The network node (200a) according to claim 19 or 20, further being configured
25 to perform the method according to any of claims 2 to 18.

22. A computer program (920) for interference suppression in a system operating according to a Time Division Duplex, TDD, pattern, the computer program comprising computer code which, when run on processing circuitry (210) of a network node (200a), causes the network node (200a) to:

detect (S102) remote interference, wherein the remote interference is detected to impact an uplink slot in the TDD pattern, and wherein, according to the TDD pattern, the uplink slot is preceded by a special slot;

5 perform (S106) interference symbol analysis, wherein the interference symbol analysis is using at least one symbol located between a last occurring downlink symbol in the special slot and a first occurring demodulation reference signal, DMRS, symbol in the uplink slot; and

perform (S108) interference suppression of the remote interference in accordance with the interference symbol analysis.

10 23. A computer program product (910) comprising a computer program (920) according to claim 22, and a computer readable storage medium (930) on which the computer program is stored.

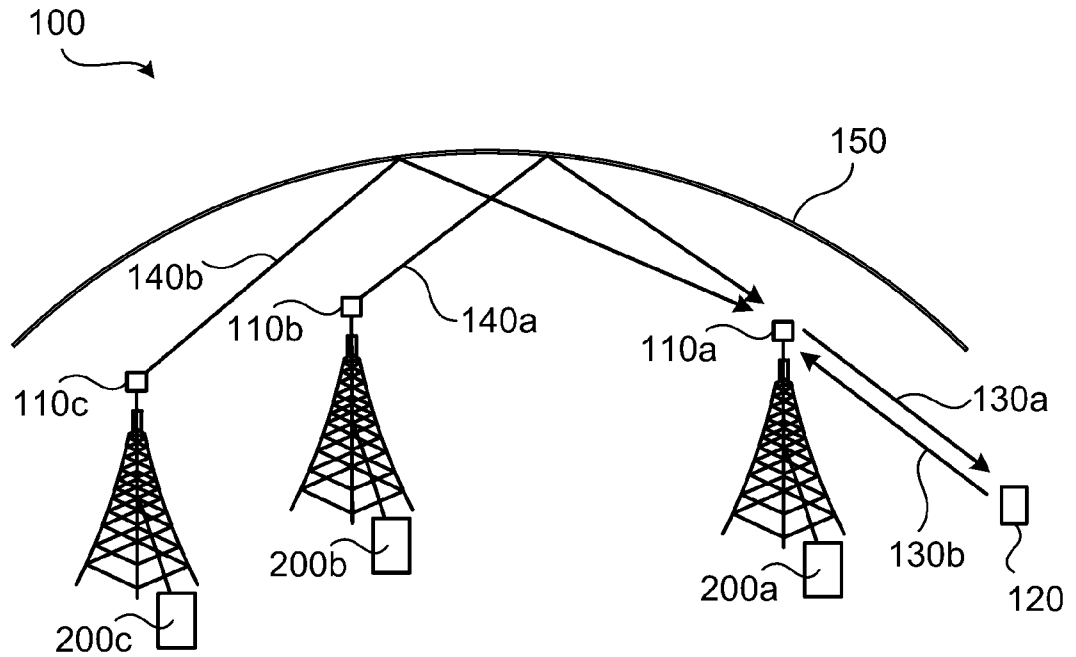


Fig. 1

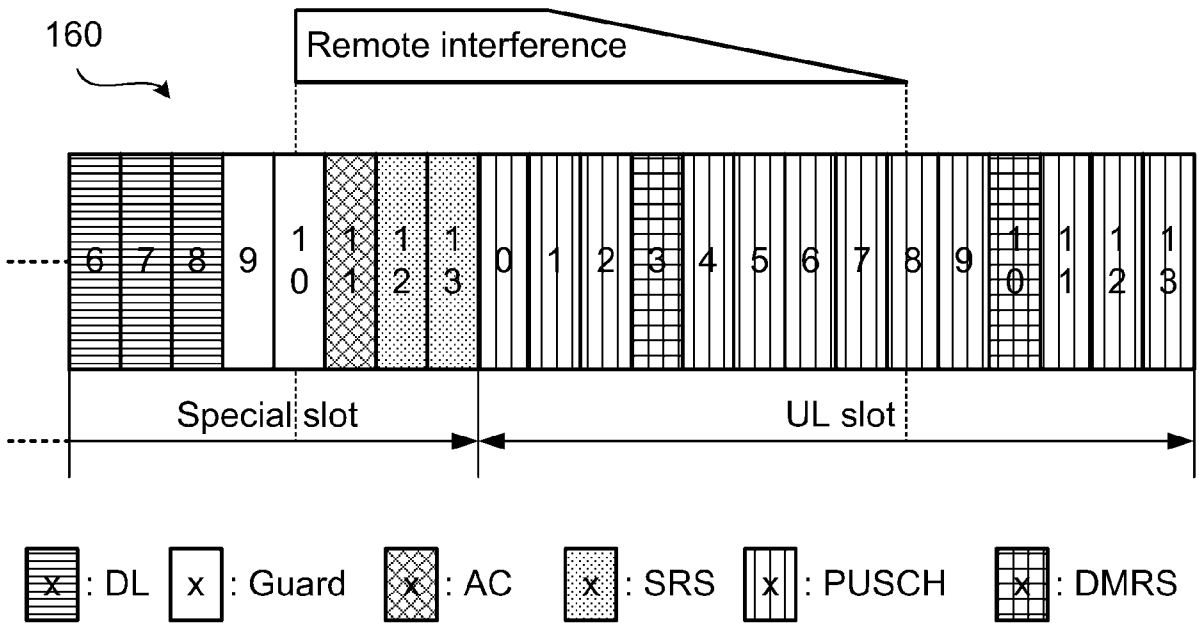


Fig. 2

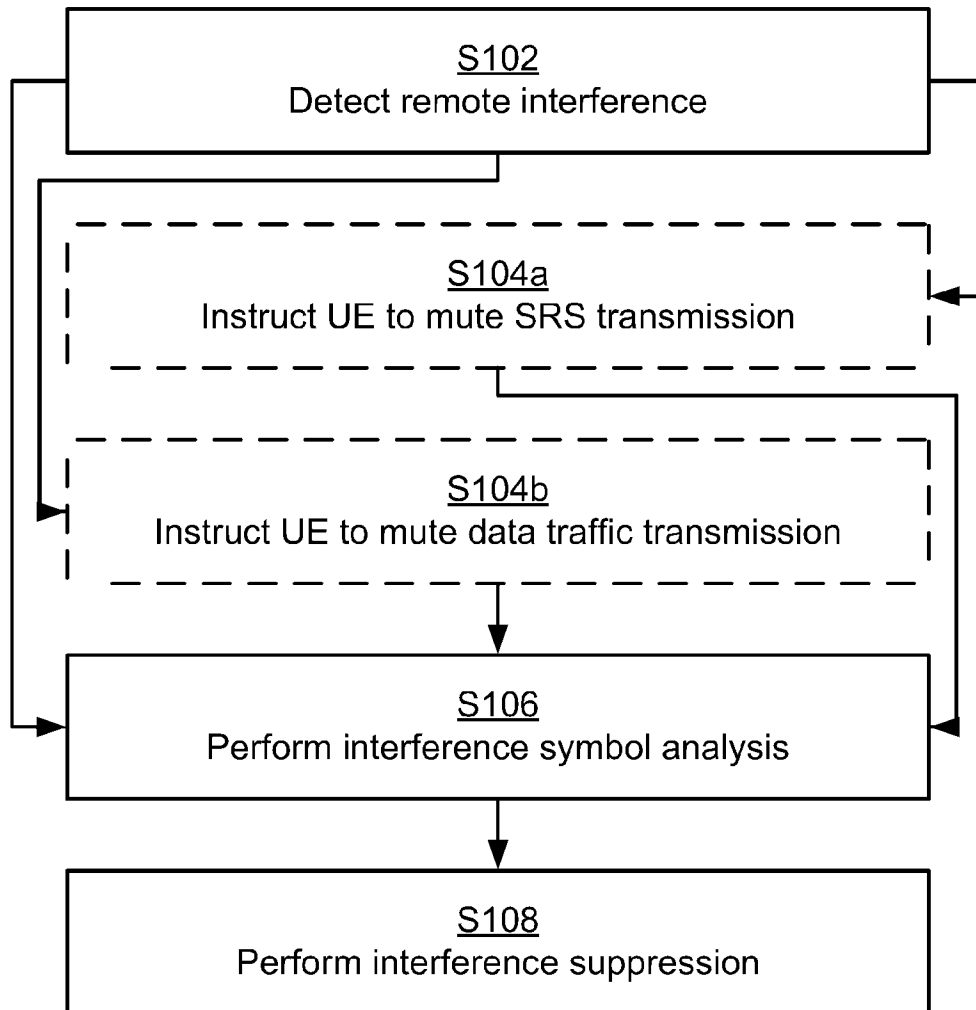


Fig. 3

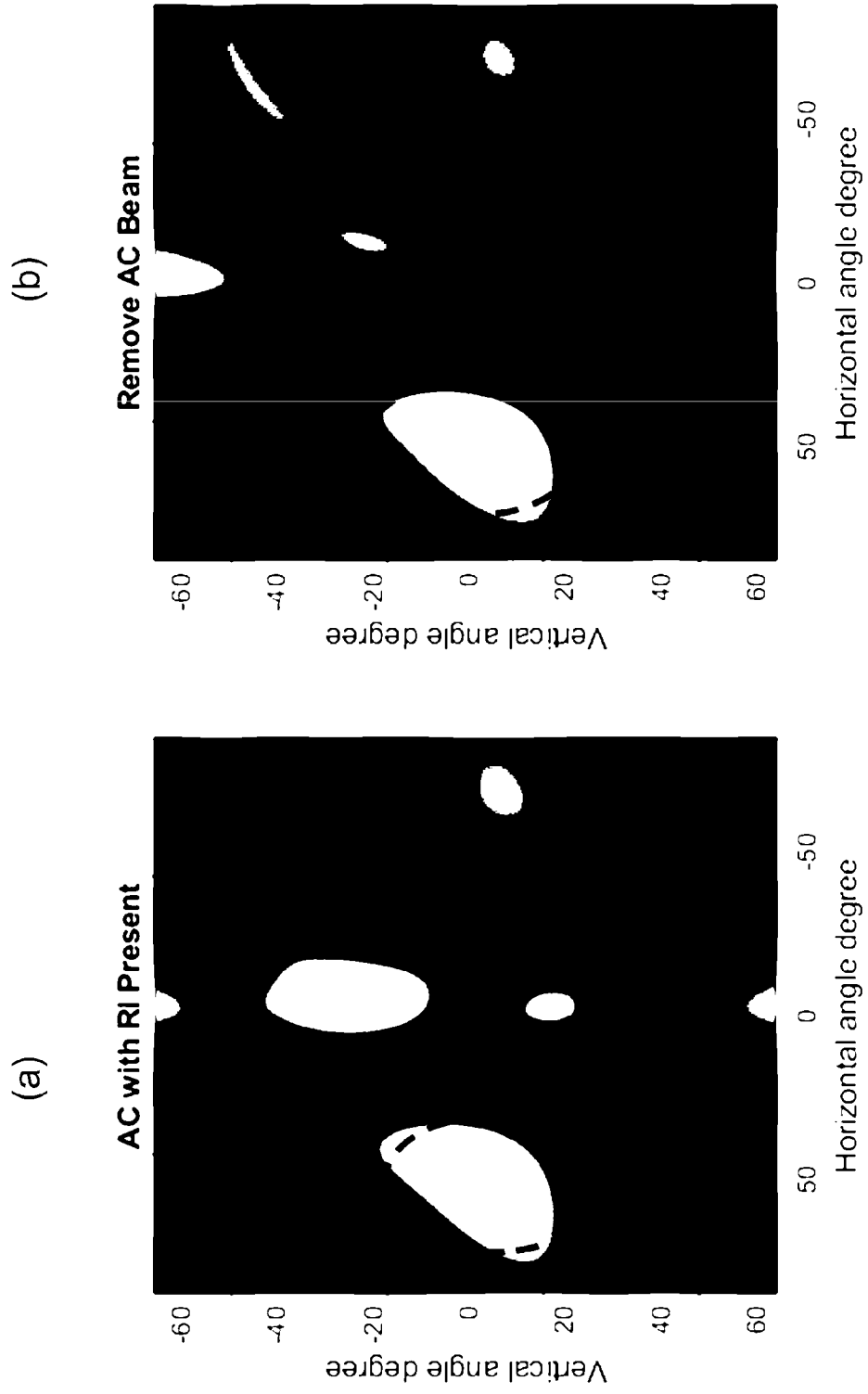


Fig. 4

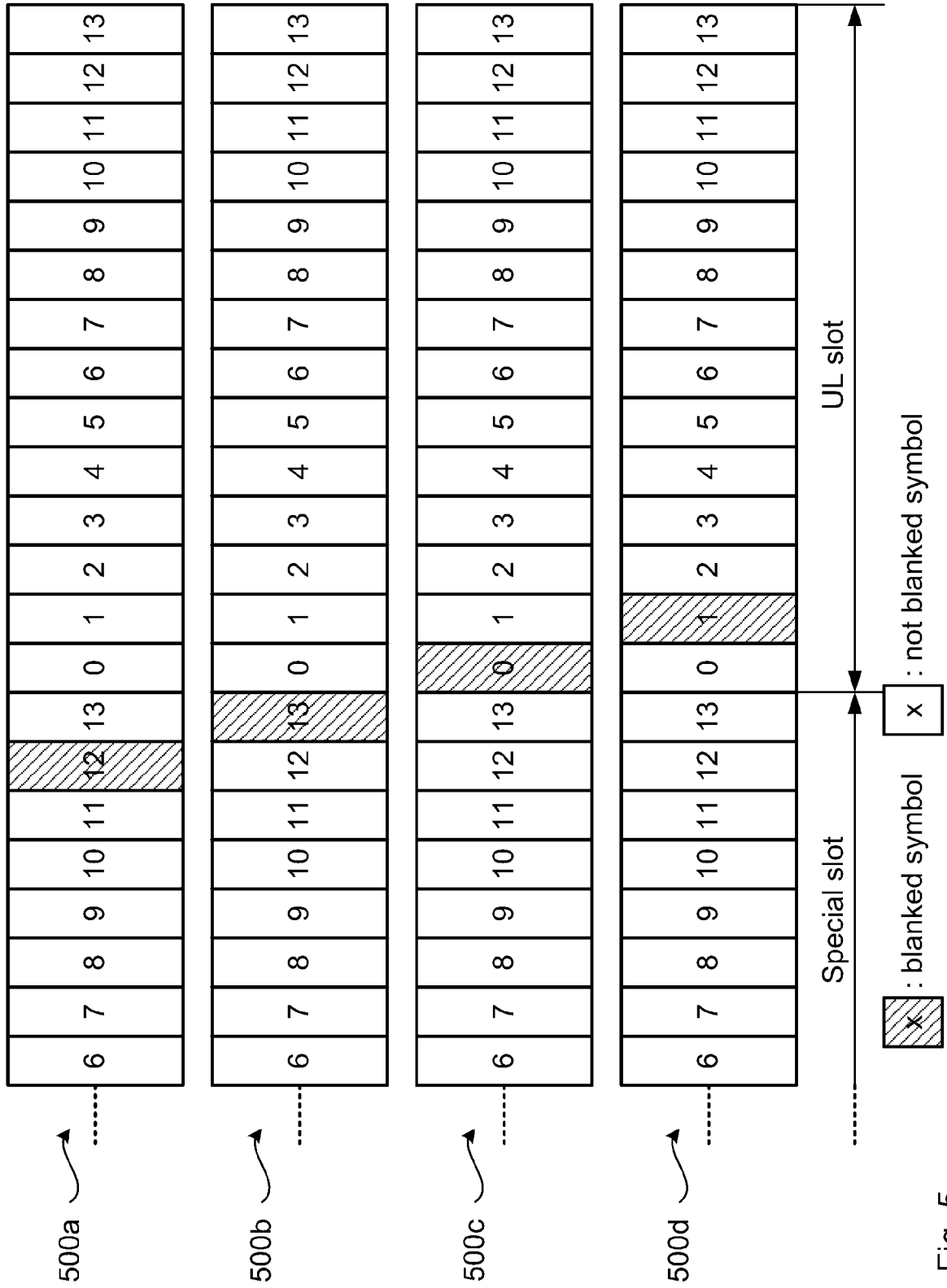


Fig. 5

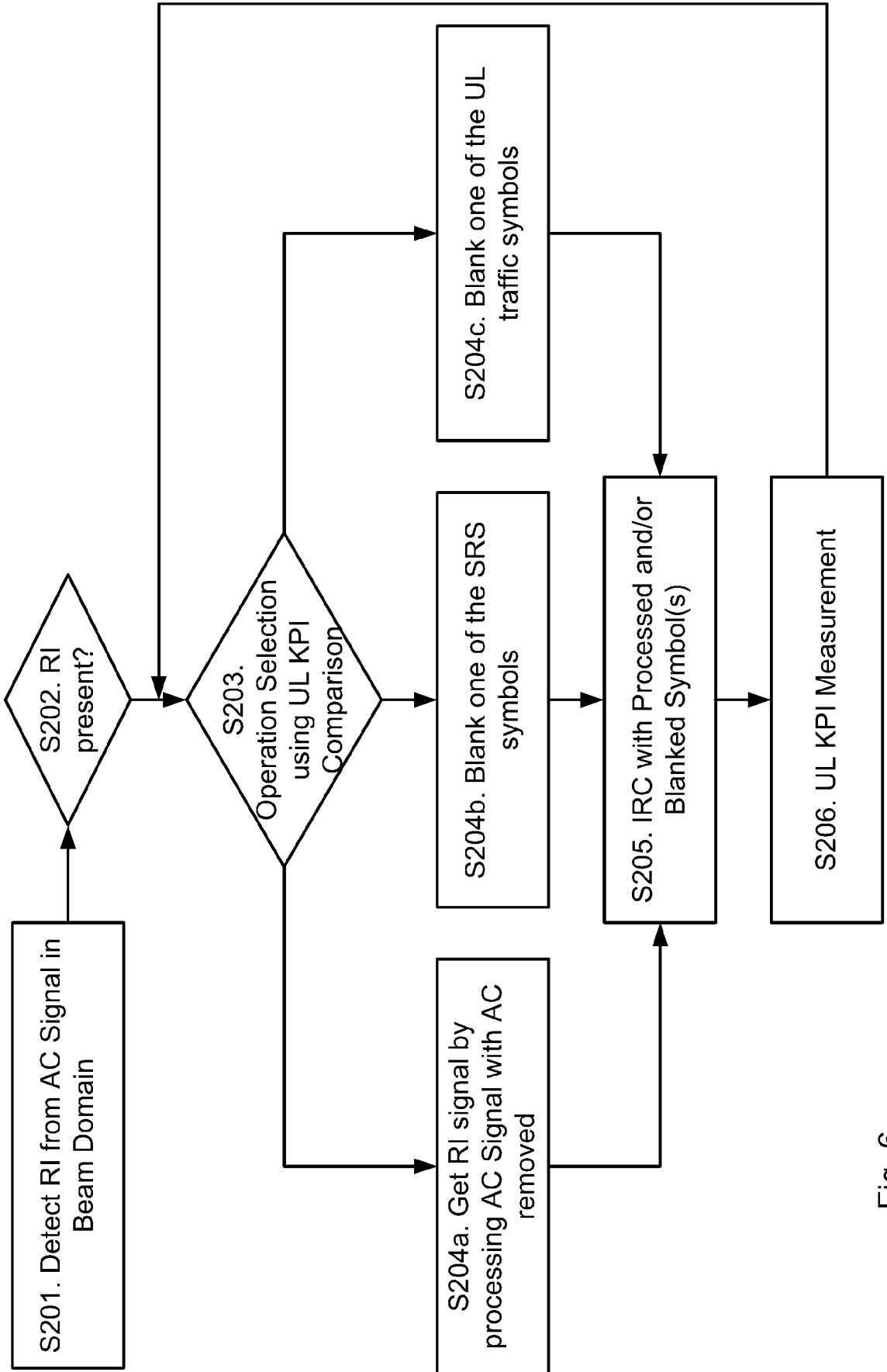


Fig. 6

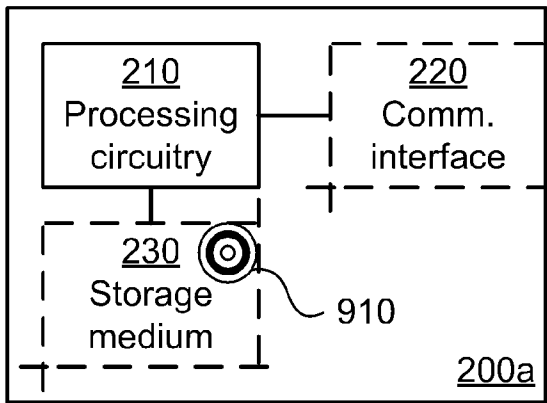


Fig. 7

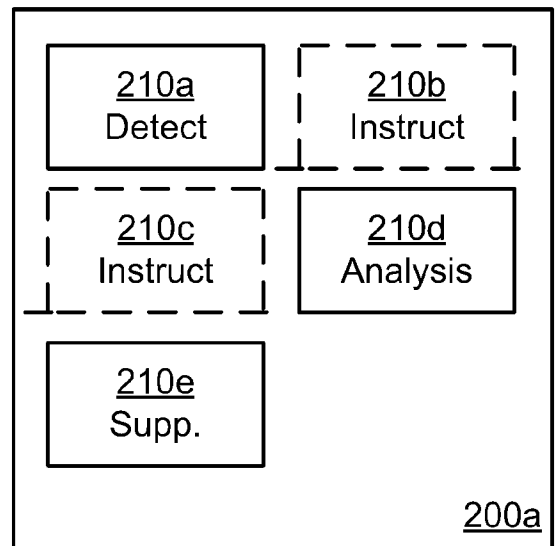


Fig. 8

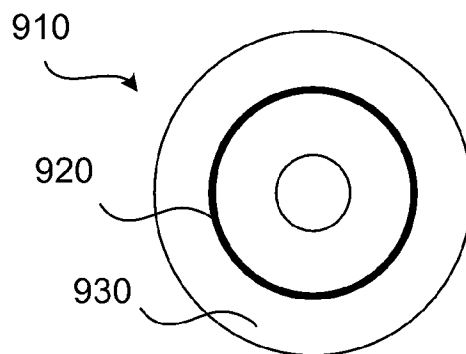


Fig. 9

INTERNATIONAL SEARCH REPORT

International application No
PCT/CN2023/098279

A. CLASSIFICATION OF SUBJECT MATTER INV. H04J11/00 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		
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, COMPENDEX, INSPEC, WPI Data		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2020/034239 A1 (ZTE CORP [CN]) 20 February 2020 (2020-02-20)	1, 16-20, 22, 23
Y	paragraph [0020] - paragraph [0031]; figure 2	1-15, 19-23
Y	----- CN 111 565 445 B (HISENSE GROUP) 4 June 2021 (2021-06-04) figures 2, 3, 6B -----	1, 19, 20, 22, 23
	-/--	
<input checked="" type="checkbox"/> Further documents are listed in the continuation of Box C. <input checked="" type="checkbox"/> 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	"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention	
"E" earlier application or patent but published on or after the international filing date	"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone	
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art	
"O" document referring to an oral disclosure, use, exhibition or other means	"&" document member of the same patent family	
"P" document published prior to the international filing date but later than the priority date claimed		
Date of the actual completion of the international search	Date of mailing of the international search report	
16 November 2023	08/12/2023	
Name and mailing address of the ISA/ European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040. Fax: (+31-70) 340-3016	Authorized officer Giglietto, Massimo	

INTERNATIONAL SEARCH REPORT

International application No
PCT/CN2023/098279

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	<p>NOKIA ET AL: "Dynamic TDD enhancements", 3GPP DRAFT; R1-2305398, 3RD GENERATION PARTNERSHIP PROJECT (3GPP), MOBILE COMPETENCE CENTRE ; 650, ROUTE DES LUCIOLES ; F-06921 SOPHIA-ANTIPOLIS CEDEX ; FRANCE</p> <p>, vol. RAN WG1, no. Incheon, Korea; 20230522 - 20230526 15 May 2023 (2023-05-15), XP052385728, Retrieved from the Internet: URL:https://ftp.3gpp.org/tsg_ran/WG1_RL1/T SGR1_113/Docs/R1-2305398.zip R1-2305398 Dynamic TDD enhancements.docx [retrieved on 2023-05-15] page 4, paragraph 2.3</p> <p align="center">-----</p>	2, 8-11, 21
Y	<p>EP 3 267 616 A1 (FUJITSU LTD [JP]) 10 January 2018 (2018-01-10) paragraph [0081] - paragraph [0087]; figure 7</p> <p align="center">-----</p>	2-7, 21
Y	<p>LG ELECTRONICS: "Discussion on mechanism for NR RIM support", 3GPP DRAFT; R1-1812570 DISCUSSIONS ON MECHANISM FOR NR RIM SUPPORT_CLEAN, 3RD GENERATION PARTNERSHIP PROJECT (3GPP), MOBILE COMPETENCE CENTRE ; 650, ROUTE DES LUCIOLES ; F-06921 SOPHIA-ANTIPOLIS CEDEX</p> <p>, vol. RAN WG1, no. Spokane, USA; 20181112 - 20181116 3 November 2018 (2018-11-03), XP051478800, Retrieved from the Internet: URL:http://www.3gpp.org/ftp/tsg%5Fran/WG1% 5FRL1/TSGR1%5F95/Docs/R1%2D1812570%2Ezip [retrieved on 2018-11-03] page 4, paragraph 2.2; figures 3, 4</p> <p align="center">-----</p> <p align="center">-/--</p>	11

INTERNATIONAL SEARCH REPORT

International application No
PCT/CN2023/098279

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	<p>YAN CHENG ET AL: "Study on potential enhancements on dynamic/flexible TDD", 3GPP DRAFT; R1-2210878; TYPE DISCUSSION; FS_NR_DUPLEX_EVO, 3RD GENERATION PARTNERSHIP PROJECT (3GPP), MOBILE COMPETENCE CENTRE ; 650, ROUTE DES LUCIOLES ; F-06921 SOPHIA-ANTIPOLIS CEDEX ; FRANCE</p> <p>/</p> <p>vol. 3GPP RAN 1, no. Toulouse, FR; 20221114 - 20221118</p> <p>7 November 2022 (2022-11-07), XP052221441, Retrieved from the Internet: URL:https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_111/Docs/R1-2210878.zip R1-2210878.docx</p> <p>[retrieved on 2022-11-07]</p> <p>page 8, paragraph 2.2.1.2 - page 10</p> <p align="center">-----</p>	11-14, 21
Y	<p>US 2021/321417 A1 (KIM DONGKYU [KR] ET AL)</p> <p>14 October 2021 (2021-10-14)</p> <p>paragraph [0217] - paragraph [0219]</p> <p align="center">-----</p>	15, 21

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Information on patent family members

International application No

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