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(54) **Title: COMMUNICATIONS METHOD AND APPARATUS**

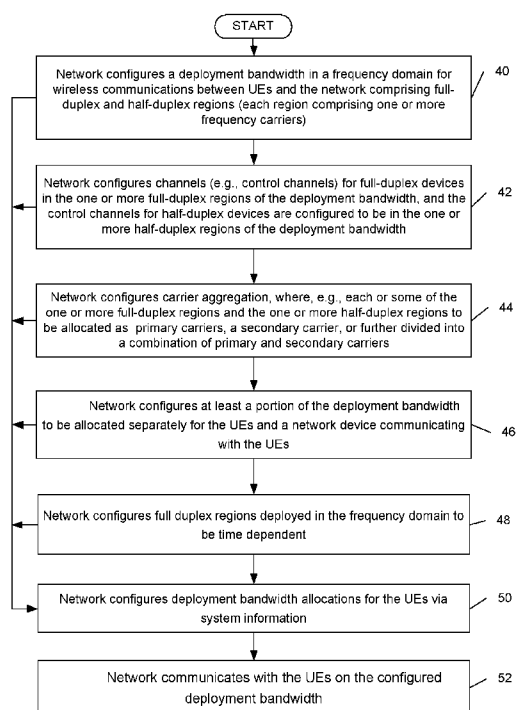


Figure 3

(57) **Abstract:** The specification and drawings present a new method, apparatus and software related product (e.g., a computer readable memory) for configuring/implementing full-duplex communications between UEs and a network on a partial frequency domain in wireless communications, e.g., in LTE systems. This may allow UEs with different transmission capabilities to operate on the same deployment bandwidth and to use time dependence of an operational mode. According to an embodiment, a network element, such as eNB, may configure a deployment bandwidth in a frequency domain for wireless communications between UEs and the network, wherein one or more full-duplex regions of the deployment bandwidth are allocated for full-duplex communications and one or more half-duplex regions of the deployment bandwidth are allocated for half-duplex communications.



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Communications Method and ApparatusTechnical Field

The present invention relates to a communications method and apparatus. The
 5 exemplary and non-limiting embodiments of this invention relate generally to wireless
 communications and more specifically to utilizing full-duplex on a partial frequency
 domain in wireless communications, e.g., in LTE systems.

Background

10 The following abbreviations that may be found in the specification and/or the
 drawing figures are defined as follows:

	3GPP	3 rd generation partnership project
	AP	access point
	BTS	base transceiver station
15	CA	carrier aggregation
	CDM	code division multiplexing
	D2D	device-to-device
	DL	downlink
	E-UTRA	evolved universal terrestrial radio access
20	eNB, eNodeB	evolved Node B /base station in an E-UTRAN system
	E-UTRAN	evolved UTRAN (LTE)
	FDM	frequency division multiplexing
	FDD	frequency division duplex
	GSM	global system for mobile communications
25	LTE	long term evolution
	LTE-A	long term evolution advanced
	MIB	management information base
	MIMO	multiple input multiple output
	MME	mobility management entity
30	MTC	machine type communication
	PRB	physical resource block

	PRACH	physical random access channel
	PRB	physical resource block
	RRC	radio resource control
	Rx, RX	reception, receiver
5	SIB	system information block
	TDD	time division duplex
	TDM	time division multiplexing
	Tx, TX	transmission, transmitter
	UE	user equipment
10	UP	uplink
	UTRAN	universal terrestrial radio access network
	WCDMA	wideband code division multiple access
	WIMAX	worldwide interoperability for microwave access
	WLAN	<u>wireless local area network</u>

15

Recently, full-duplex communications have attracted a lot of interest to enhance spectral efficiency in local area communications. The full-duplex communications are based on the principle in which radios can transmit and receive simultaneously on the same frequency band resulting in a self-interference problem.

20 The self-interference problem is mainly caused by the large imbalance between the transmitted signal power and received signal power. Typically, the transmitted signal power can be a few orders of magnitude larger than the received signal power. As a result, the received signal may be severely degraded by its own transmitted signal.

25 General background for the recent full duplex studies can be found from the following references:

Jung II Choi, Mayank Jainy, Kannan Srinivasany, Philip Levis, Sachin Katti, "Achieving Single Channel, Full Duplex Wireless Communication" , In the Proceedings of the 16th Annual International Conference on Mobile Computing and Networking (Mobicom, held Chicago, Illinois, USA, September 20-24, 2010);

30 Melissa Duarte and Ashutosh Sabharwal," Full-Duplex Wireless Communications Using Off-The-Shelf Radios: Feasibility and First Results", in the

Proceedings of the 44th annual Asilomar conference on signals, systems, and computers (held in November 7–10, 2010 in Monterey, California, USA);

Melissa Duarte, Chris Dick and Ashutosh Sabharwal “Experiment-driven Characterization of Full-Duplex Wireless Systems”, Submitted to IEEE Transactions on Wireless Communications, July 2011; (The paper can be found in the following link: <http://arxiv.org/abs/1107.1276>);

Evan Everett, Melissa Duarte, Chris Dick, and Ashutosh Sabharwal “Empowering Full-Duplex Wireless Communication by Exploiting Directional Diversity”, accepted to the 45th annual Asilomar conference on signals, systems, and computers (held in November 7–10, 2010 in Monterey, California, USA); and Achaleshwar Sahai, Gaurav Patel and Ashutosh Sabharwal “Pushing the limits of Full-duplex: Design and Real-time Implementation”, Rice University technical report TREE1104, February 2011. (The paper can be found in the following link: http://warp.rice.edu/trac/wiki/TechReport2011_FullDuplex)

It may be assumed that in future cellular networks access points and devices will support full-duplex transmission. However, due to the different types of devices on the market, not all of the devices may support full-duplex transmission due to the cost issue (e.g., low capability phones) or the pre-determined service/traffic type (e.g. MTC-devices).

For the overall system performance point of view it would be beneficial to support full duplex for the so-called high end, high transmission capability devices which require such transmission scheme for their current services and at the same time support the non-full-duplex devices.

Summary

According to a first aspect of the invention, there is provided a communications method comprising: configuring by a network a deployment bandwidth in a frequency domain for wireless communications between user equipments and the network, wherein one or more full-duplex regions of the deployment bandwidth are allocated for full-duplex communications and one or more half-duplex regions of the deployment bandwidth are allocated for half-duplex

communications; and communicating with the user equipments on the configured deployment bandwidth.

According to a second aspect of the invention, there is provided a communications apparatus comprising: a processing system arranged to cause the apparatus to: configure a deployment bandwidth in a frequency domain for wireless communications between user equipments and the network, wherein one or more full-duplex regions of the deployment bandwidth are allocated for full-duplex communications and one or more half-duplex regions of the deployment bandwidth are allocated for half-duplex communications; and communicate with the user equipments on the configured deployment bandwidth.

The processing system may comprise at least one processor and a memory storing a set of computer instructions.

According to a third aspect of the invention, there is provided a computer readable medium comprising a set of instructions, which, when executed on an apparatus in a network causes the apparatus to perform the method of the first aspect of the invention.

Brief Description of the Drawings

For a better understanding of the nature and objects of the present invention, reference is made to the following detailed description taken in conjunction with the following drawings, in which:

Figures 1-2 are frequency diagrams demonstrating bandwidth deployment for a partial full-duplex operation, according to exemplary embodiments of the invention;

Figure 3 is a flow chart demonstrating implementation of exemplary embodiments of the invention performed by a network element (e.g., eNB); and

Figure 4 is a block diagram of wireless devices for practicing exemplary embodiments of the invention.

Detailed Description

A new method, apparatus, and software related product (e.g., a computer readable memory) are presented for configuring/implementing full-duplex

communications between UEs and a network on a partial frequency domain in wireless communications, e.g., in LTE systems. This may allow UEs with different transmission capabilities to operate on the same deployment bandwidth and to use time dependence of an operational mode.

5 The embodiments described herein may apply to future TDD based cellular systems, like LTE-A. Also FDD systems may also be used based on the embodiments described herein. In addition to 3GPP cellular systems such as GSM and WCDMA, the technique may be also applicable to IEEE systems defined by 802.11 (WLAN) and 802.16 (WIMAX). In general, the invention may be applicable (depending on the
10 technical challenges) to cellular macro and micro deployments and maybe even more applicable to local area deployments such as femto, pico and body area networks. D2D communication may be also considered to be one application area for the full-duplex.

 According to an embodiment of the invention, a network element, such as
15 eNB, may configure a deployment bandwidth in a frequency domain for wireless communications between UEs and the network, wherein one or more full-duplex regions of the deployment bandwidth are allocated for full-duplex communications and one or more half-duplex regions of the deployment bandwidth are allocated for half-duplex communications.

20 For example, in one embodiment the full-duplex transmission may be used on the partial resources on the deployment bandwidth, as illustrated in the exemplary Figure 1, where the full duplex regions **22** are located at edges of the deployment bandwidth **20** and the half-duplex region **24** is located in the middle of the deployment bandwidth **20**. Alternatively, the half-duplex regions may be located at
25 the edges of the deployment bandwidth **20** with the full-duplex regions in the middle. Also, the deployment bandwidth may comprise a plurality of the full-duplex regions and/or a plurality of the half-duplex regions. In general, the deployment bandwidth may comprise one or more full-duplex regions and/or one or more half-duplex regions at arbitrary positions in the deployment bandwidth.

30 In one further embodiment the network may configure the control channels (e.g., uplink feedback channels or DL scheduling channels) for the half-duplex

devices to the half-duplex region/regions and separately the full-duplex control channels for the full-duplex devices to the full-duplex region/regions.

It is further noted that each full-duplex region or each half-duplex region in the deployment bandwidth may comprise one or more multiple component carriers.

5 Moreover, in a further embodiment the network may aggregate multiple component carriers, possibly at different bandwidths regions, to be used for the full-duplex or half-duplex communications. The aggregated carriers for full-duplex and half-duplex communications may be either contiguous or non-contiguous in a frequency domain. As a result of carrier aggregation enabling the full-duplex
10 communication, the utilization of available frequency spectrum may be further enhanced.

Figure 2 illustrates an embodiment, wherein the deployment possibilities using primary and secondary carriers are utilized. The deployment may comprise multiple secondary carriers which are configured to be either half duplex, full-duplex or
15 combined full/half-duplex. Thus, each of the one or more full-duplex regions and the one or more half-duplex regions may be allocated as a primary carrier, a secondary carrier, or further divided into a combination of primary and secondary carriers.

In one further non-limiting embodiment the deployment bandwidth allocation may be used in an UL band/phase of the system to keep, for example, communication
20 properties of legacy UE devices substantially similar and to enable any added receiver complexity to be implemented at eNB/AP/BTS side. Furthermore, this mode of operation may provide that each UE receives and transmits in a normal TDD fashion, i.e., transmitted and received signals never collide, and only the eNB/AP/BTS supporting full duplex operation may receive transmission from one UE device and
25 simultaneously transmit to another UE device on a DL band/phase. In this embodiment at least a portion of the deployment bandwidth is allocated separately for the UEs and a network device, like eNB/AP/BTS, communicating with the UEs. In this manner the network device may be configured for the full-duplex communications and a portion or all of the UEs may be configured for the half-
30 duplex communications. Thus the network device/element like eNB may be configured only for the full-duplex communications with the UEs. In another

embodiment the network may configure a time domain utilization of the full-duplex operation (in addition to the frequency domain utilization). For example, the network may configure subframes in the full-duplex region (e.g., in LTE-A system) to be full-duplex subframes or half-duplex subframes in time domain. Also, different UE groups
5 may have different full-duplex time periods.

Moreover, the information about the time domain utilization of the full-duplex operation may be configured by the network and provided to the UEs via system information broadcast such as SIB and/or MIB in LTE, or with the user specific control signaling such as RRC signaling.

10 Alternatively, the network may inform the UEs via system information which time domains utilize the non-full duplex (half-duplex) mode and by extension the UEs will also know when the full-duplex mode is to be in effect.

The network may configure deployment bandwidth allocations for the UEs, described herein, via system information.

15 Figure 3 shows an exemplary flow chart demonstrating configuring by the network a deployment bandwidth in a frequency domain for wireless communications between UEs and the network according to exemplary embodiments disclosed herein. It is noted that the order of steps shown in Figure 3 is not required, so in principle the various steps may be performed out of the illustrated order. Also certain steps may be
20 skipped, different steps may be added or substituted, or selected step/steps or groups of steps may be performed separately.

In a method according to this exemplary embodiment, as shown in Figure 3, in a first step **40**, the network configures a deployment bandwidth in a frequency domain for wireless communications between UEs and the deployment bandwidth comprises
25 full-duplex and half-duplex regions (each region may comprise one or more frequency carriers), as described herein and shown, e.g., in Figures 1 and 2.

In a next step **42**, the network configures channels (e.g., control channels) for the full-duplex devices in the one or more full-duplex regions of the deployment bandwidth, and the control channels for half-duplex devices are configured to be in
30 the one or more half-duplex regions of the deployment bandwidth.

In a next step **44**, the network configures carrier aggregation, where, for example, each or some of the one or more full-duplex regions and the one or more half-duplex regions to be allocated as a primary carrier, a secondary carrier, or further divided into a combination of primary and secondary carriers, as described herein and illustrated in Figure 2.

In a next step **46**, the network allocates to UEs at least one half-duplex region for UL only, and the network utilizes the at least one allocated half-duplex region as full-duplex.

In a next step **48**, network configures at least a portion of the deployment bandwidth in the frequency domain to be time dependent, e.g., the full-duplex regions deployed in the frequency domain may be time dependent.

The results of the deployment bandwidth allocations presented in steps **42-48** in Figure 3 may be configured by the network to the UE via system information in step **50**. In a next step **52**, the network communicates with the UEs using the configured deployment bandwidth.

Figure 4 shows an example of a block diagram demonstrating LTE devices including an eNB **80** comprised in a network **10**, and UE1 **82** and UE2 **86**, according to an embodiment of the invention. Figure 4 is a simplified block diagram of various electronic devices that are suitable for practicing the exemplary embodiments of this invention, e.g., in reference to Figures 1-3, and a specific manner in which components of an electronic device are configured to cause that electronic device to operate. Each of the UEs **82** and **86** may be implemented as a mobile phone, a wireless communication device, a camera phone, a portable wireless device and the like.

The eNB **80** may comprise, e.g., at least one transmitter **80a** at least one receiver **80b**, at least one processor **80c** at least one memory **80d** and a deployment bandwidth configuring application module **80e**. The transmitter **80a** and the receiver **80b** and corresponding antennas (not shown in Figure 4) may be configured to provide wireless communications with the UEs **82** and **86** (and others not shown in Figure 4) according to the embodiment of the invention. The transmitter **80a** and the receiver **80b** may be generally means for transmitting/receiving and may be

implemented as a transceiver, or a structural equivalence (equivalent structure) thereof. It is further noted that the same requirements and considerations are applied to transmitters and receivers of the devices **82** and **86**.

Furthermore, the eNB **80** may further comprise communicating means such as a modem **80f**, e.g., built on an RF front end chip of the eNB **80**, which also carries the TX **80a** and RX **80b** for bidirectional wireless communications via data/control/broadcasting wireless links **81a** and **81b** with the UEs **82** and **86**. The same concept is applicable to UE devices **82** and **86** shown in Figure 4.

Various embodiments of the at least one memory **80d** (e.g., computer readable memory) may include any data storage technology type which is suitable to the local technical environment, including but not limited to semiconductor based memory devices, magnetic memory devices and systems, optical memory devices and systems, fixed memory, removable memory, disc memory, flash memory, DRAM, SRAM, EEPROM and the like. Various embodiments of the processor **80c** include but are not limited to general purpose computers, special purpose computers, microprocessors, digital signal processors (DSPs) and multi-core processors. Similar embodiments are applicable to memories and processors in other devices **82** and **86** shown in Figure 4.

The deployment bandwidth/mode configuring application module **80e** may provide various instructions for performing steps **40-50** in Figure 3. The module **80e** may be implemented as an application computer program stored in the memory **80d**, but in general it may be implemented as software, firmware and/or hardware module or a combination thereof. In particular, in the case of software or firmware, one embodiment may be implemented using a software related product such as a computer readable memory (e.g., non-transitory computer readable memory), computer readable medium or a computer readable storage structure comprising computer readable instructions (e.g., program instructions) using a computer program code (i.e., the software or firmware) thereon to be executed by a computer processor.

Furthermore, the module **80e** may be implemented as a separate block or may be combined with any other module/block of the eNB **80**, or it may be split into several blocks according to their functionality.

The UE1 **82** and UE2 **86** may have similar components as the eNB **80**, as shown in Figure 5, so that the above discussion about components of the eNB **80** is fully applicable to the components of the UE1 **82** and UE2 **86**,

5 It is noted that various non-limiting embodiments described herein may be used separately, combined or selectively combined for specific applications.

Further, some of the various features of the above non-limiting embodiments may be used to advantage without the corresponding use of other described features. The foregoing description should therefore be considered as merely illustrative of the principles, teachings and exemplary embodiments of this invention, and not in
10 limitation thereof.

It is to be understood that the above-described arrangements are only illustrative of the application of the principles of the present invention. Numerous modifications and alternative arrangements may be devised by those skilled in the art without departing from the scope of the invention, and the appended claims are
15 intended to cover such modifications and arrangements.

Claims

1. A communications method, comprising:
5 configuring by a network a deployment bandwidth in a frequency domain for wireless communications between user equipments and the network, wherein one or more full-duplex regions of the deployment bandwidth are allocated for full-duplex communications and one or more half-duplex regions of the deployment bandwidth are allocated for half-duplex communications; and
10 communicating with the user equipments on the configured deployment bandwidth.
2. The method of claim 1, wherein the configured deployment bandwidth comprises two full-duplex regions located at opposed edges of the deployment
15 bandwidth.
3. The method of claim 1, wherein the configured deployment bandwidth comprises two half-duplex portions located at opposed edges of the deployment
20 bandwidth.
4. The method of any of claims 1 to 3, wherein the configured deployment bandwidth comprises a plurality of the full-duplex regions.
5. The method of any preceding claim, further comprising configuring a
25 control channel for full-duplex devices to be in the one or more full-duplex regions of the deployment bandwidth and for half-duplex devices to be in the one or more half-duplex regions of the deployment bandwidth.
6. The method of any preceding claim, wherein each full-duplex region or
30 each half-duplex region in the deployment bandwidth comprises one or more component carriers.

5 7. The method of any preceding claim, further comprising configuring carrier aggregation, wherein each or some of the one or more full-duplex regions and the one or more half-duplex regions are allocated as a primary carrier, a secondary carrier, or further divided into a combination of primary and secondary carriers.

10 8. The method of any preceding claim, wherein at least one region of the deployment bandwidth is allocated as a half-duplex region to all or some of the user equipments for uplink communications and as a full-duplex region for a network device communicating with the all or some of the user equipments.

15 9. The method of any preceding claim, wherein a network device communicating with all or some of the user equipments is configured for the full-duplex communications and a part or all of the user equipments are configured for the half-duplex communications.

20 10. The method of any preceding claim, wherein an eNB of the network is configured only for the full-duplex communications with the user equipments.

11. The method of any preceding claim, further comprising configuring in a time domain the full-duplex regions deployed in the frequency domain.

25 12. The method of any preceding claim, wherein different groups of the user equipments are configured to have different full-duplex time periods.

30 13. A communications apparatus comprising:
a processing system arranged to cause the apparatus to:
configure a deployment bandwidth in a frequency domain for wireless communications between user equipments and the network, wherein one or more full-duplex regions of the deployment bandwidth are allocated for full-

duplex communications and one or more half-duplex regions of the deployment bandwidth are allocated for half-duplex communications; and communicate with the user equipments on the configured deployment bandwidth.

5

14. The apparatus of claim 13, wherein the configured deployment bandwidth comprises two half-duplex portions located at opposed edges of the deployment bandwidth.

10

15. The apparatus of claim 13 or 14, wherein the processing system is further arranged to cause the apparatus to:

configure a control channel for full-duplex devices to be in the one or more full-duplex regions of the deployment bandwidth and for half-duplex devices to be in the one or more half-duplex regions of the deployment bandwidth.

15

16. The apparatus of claim 13 or 14 or 15, wherein the processing system is further arranged to cause the apparatus to:

configure carrier aggregation, wherein each or some of the one or more full-duplex regions and the one or more half-duplex regions are allocated as a primary carrier, a secondary carrier, or further divided into a combination of primary and secondary carriers.

20

17. The apparatus of any of claims 13 to 16, wherein at least one region of the deployment bandwidth is allocated as a half-duplex region to all or some of the user equipments for uplink communications and as a full-duplex region for a network device communicating with the all or some of the user equipments.

25

18. The apparatus of claim 17, wherein a network device is configured for the full-duplex communications and a part or all of the user equipments are configured for the half-duplex communications.

30

19. The apparatus of any of claims 13 to 18, wherein the computer system is further arranged to cause the apparatus to:

5 configure in a time domain the full-duplex regions deployed in the frequency domain.

20. The apparatus of claim 19, wherein different groups of the user equipments are configured to have different full-duplex time periods.

10 21. The apparatus of any of claims 13 to 20, wherein an eNB of the network is configured only for the full-duplex communications with the user equipments.

15 22. The apparatus of any of claims 13 to 22, wherein the apparatus comprises an eNB.

23. A computer readable medium comprising a set of instructions, which, when executed on an apparatus in a network cause the apparatus to perform the method of any of claims 1 to 12.

20

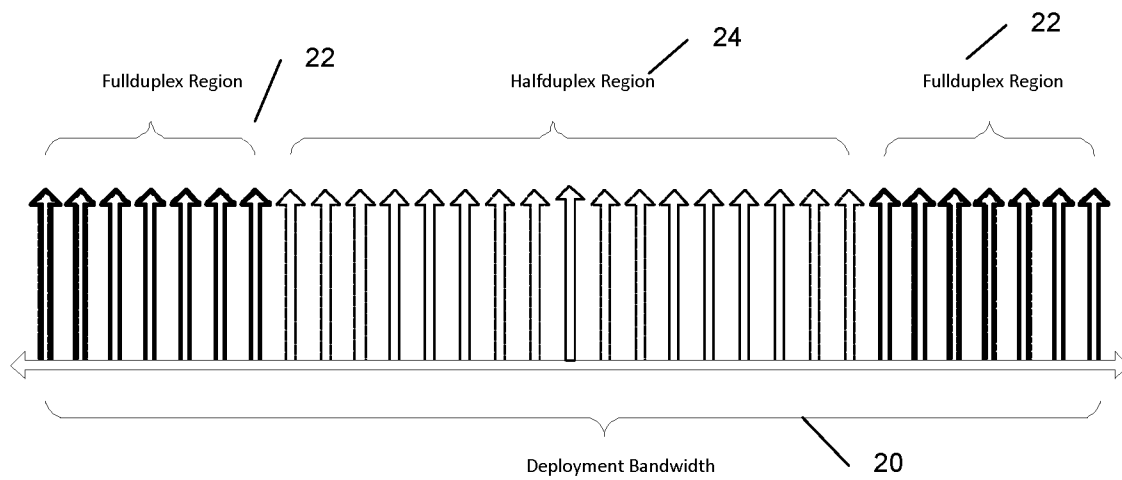


Figure 1

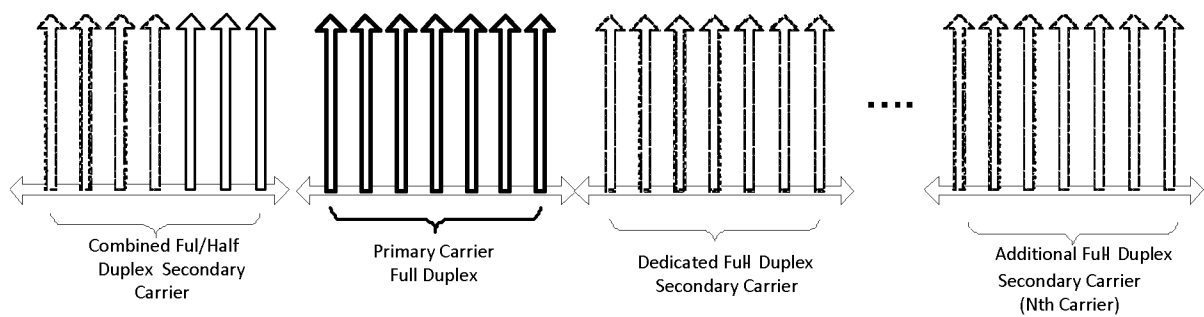
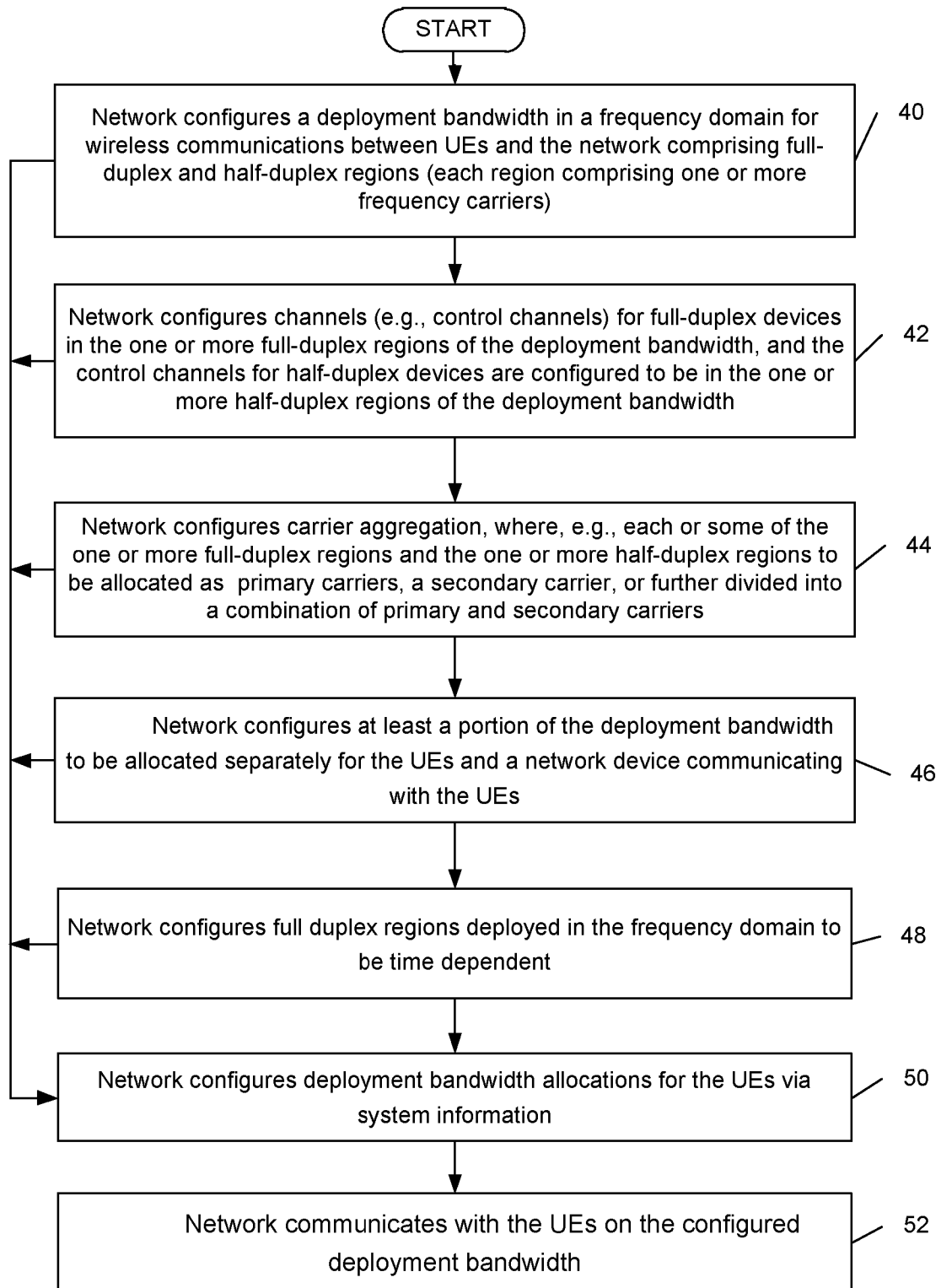
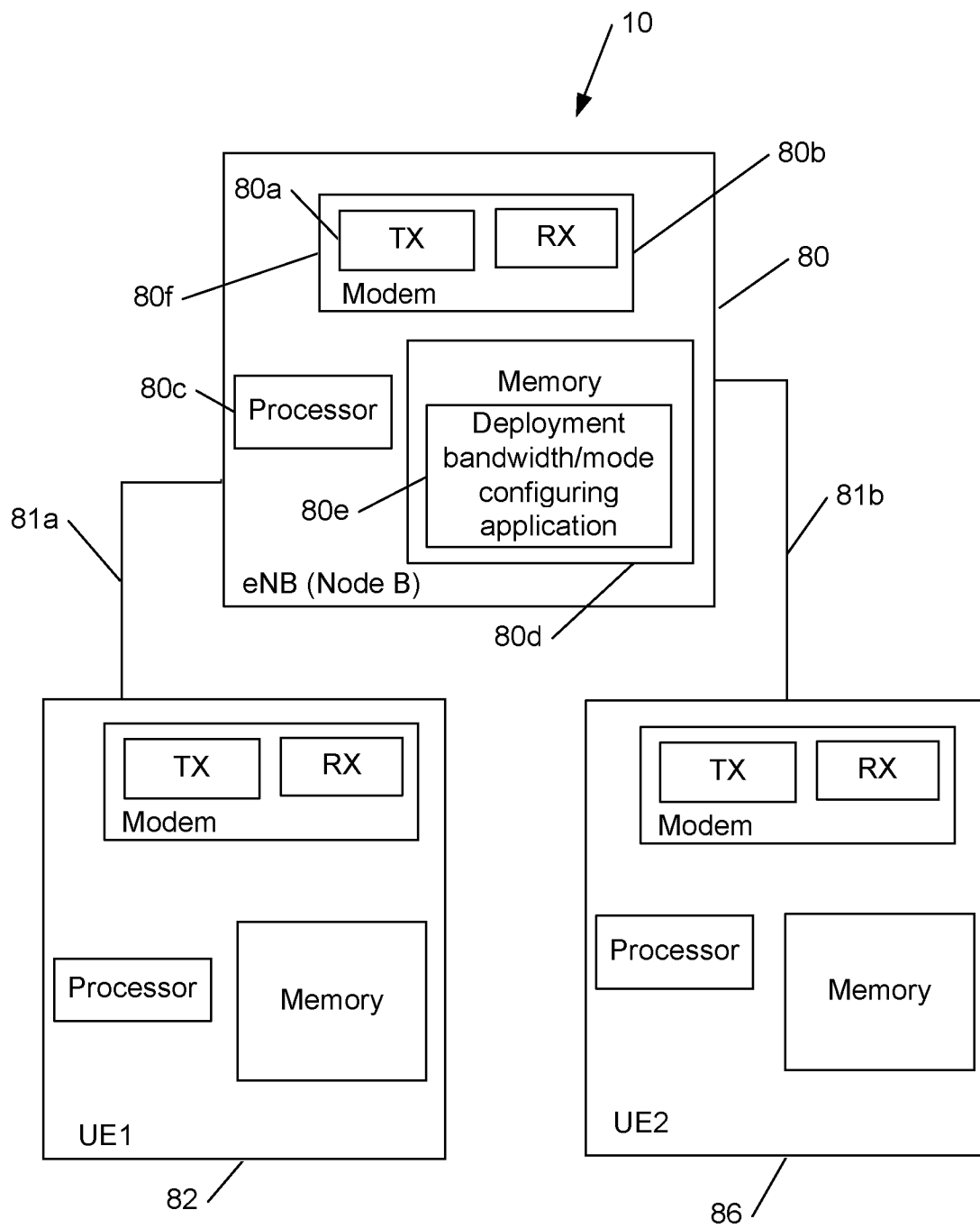


Figure 2

**Figure 3**

**Figure 4**

INTERNATIONAL SEARCH REPORT

International application No

PCT/IB2013/050487

A. CLASSIFICATION OF SUBJECT MATTER

INV. H04W72/04 H04L5/00
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)

H04W 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, WPI Data, COMPENDEX

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2009/268645 A1 (CHINDAPOL AIK [US] ET AL) 29 October 2009 (2009-10-29)	1-5, 8-15, 17-23
Y	page 2, paragraph 23 - page 6, paragraph 55; figure 3 ----- -/--	6,7,16

☒ 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

8 May 2013

Date of mailing of the international search report

17/05/2013

Name and mailing address of the ISA/

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INTERNATIONAL SEARCH REPORT

International application No

PCT/IB2013/050487

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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