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(54) Title: IDENTIFYING DATA IN MACHINE-TYPE COMMUNICATION

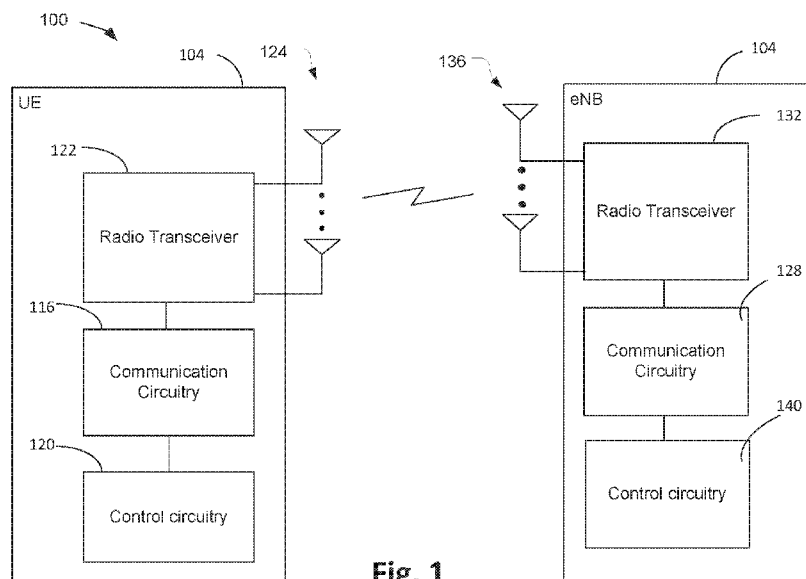


Fig. 1

(57) Abstract: Embodiments of the present disclosure describe systems, devices, and methods to identify data in machine-type communication. Various embodiments may include an evolved node B(eNB) that assigns frequency offsets to one or more of plural machine-type communication (MTC) user equipment (UE), receives plural repeated bursts of MTC data from each of the plural MTC UE over a shared transmission resource with phase shift between the plural repeated bursts based upon the frequency offsets, and compensates for the phase shift to identify the MTC data corresponding to each of the plural the MTC UE.

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IDENTIFYING DATA IN MACHINE-TYPE COMMUNICATION

Field

Embodiments of the present disclosure generally relate to the field of wireless communication, and more particularly, to methods and apparatuses for machine-type communications in cellular networks.

Background

Machine-type communication (MTC) is a promising and emerging technology to enable a ubiquitous computing environment towards the concept of “Internet of Things (IoT),” including the cellular Internet of Things (CIoT) in which MTC is carried over a wireless or cellular network. Potential MTC-based applications include smart metering, healthcare monitoring, remote security surveillance, intelligent transportation systems, etc. Existing mobile broadband networks were designed to optimize performance mainly for human types of communications and thus are not designed or optimized to address the MTC-related issues.

Brief Description of the Drawings

Embodiments will be readily understood by the following detailed description in conjunction with the accompanying drawings. To facilitate this description, like reference numerals designate like structural elements. Embodiments are illustrated by way of example and not by way of limitation in the figures of the accompanying drawings.

Fig. 1 schematically illustrates a wireless communication environment in accordance with various embodiments.

Fig. 2 is a flowchart describing operations of identifying data in MTC in accordance with various embodiments.

Fig. 3 is a flowchart 300 describing operations of identifying MTC data in accordance with some embodiments.

Fig. 4 is an illustration of a burst in an EC-GSM system employing GMSK modulation.

Fig. 5 is a flowchart describing operations of identifying MTC data in accordance with some embodiments.

Figs. 6-9 are illustrations embodiments of bursts.

Fig. 10 is a flowchart describing operations of identifying MTC data

Fig. 11 illustrates, for one embodiment, example components of an electronic device.

Detailed Description

5 Various aspects of the illustrative embodiments will be described using terms commonly employed by those skilled in the art to convey the substance of their work to others skilled in the art. However, it will be apparent to those skilled in the art that alternate embodiments may be practiced with only some of the described aspects. For purposes of explanation, specific numbers, materials, and configurations are set forth in
10 order to provide a thorough understanding of the illustrative embodiments. However, it will be apparent to one skilled in the art that alternate embodiments may be practiced without the specific details. In other instances, well-known features are omitted or simplified in order not to obscure the illustrative embodiments.

Further, various operations will be described as multiple discrete operations, in
15 turn, in a manner that is most helpful in understanding the illustrative embodiments; however, the order of description should not be construed as to imply that these operations are necessarily order dependent. In particular, these operations need not be performed in the order of presentation.

The phrase “in some embodiments” is used repeatedly. The phrase generally does
20 not refer to the same embodiments; however, it may. The terms “comprising,” “having,” and “including” are synonymous, unless the context dictates otherwise.

The phrases “A or B,” “A/B,” and “A and/or B” mean (A), (B), or (A and B).

Illustrative embodiments of the present disclosure include, but are not limited to, methods, systems, computer-readable media, and apparatuses that may enable
25 identification of data in MTC services and applications in cellular networks with increased uplink (UL) capacity.

Fig. 1 schematically illustrates a wireless communication system 100 in accordance with various embodiments. The system 100 may include a user equipment (UE) 104 and base station (BS) such as, for example, evolved node base station (eNodeB or eNB) 108. The eNB 108 may be an access node of a 3rd Generation Partnership Project (3GPP) network and may incorporate or apply any of a variety of standards, formats, or conventions including, Global System for Mobile Communications (GSM), Extended Coverage GSM (EC-GSM), Long Term Evolution (LTE), etc.
30

The UE 104 may be any type of computing device equipped with wireless communication circuitry and adapted to communicate through a RAN according to, for example, one or more 3GPP Technical Specifications. The UE 104 may include, but is not limited to, a phone, a computer, a sensor, or any other device that is configured for wireless communication through a RAN. In various embodiments, the UE 104 may be a UE primarily designed for MTC and may be referred to as an MTC UE 104.

The UE 104 may include communication circuitry 116, control circuitry 120, radio transceiver 122, and one or more antennas 124. Communication circuitry 116 may interface with the radio transceiver 122 to receive radio frequency (RF) signals from and/or send RF signals to one or more components, for example, eNB 108, over an air interface via the one or more antennas 124 according to one or more standard protocols. In embodiments, the MTC UE 104 may upload or uplink to eNB 108 data from a machine, device, system, etc. (not shown) that may be associated with, connected to, or in communication with MTC UE 104. Such data may be referred to as MTC data, and the MTC UE 104 together with its associated machine, device, system, etc. (not shown) may be referred to as a Cellular Internet of Things device (CIoT device). In embodiments, the MTC UE 104 may communicate MTC data to eNB 108 in burst transmissions, which may include small burst transmissions that may be occasional or infrequent, and/or periodic or aperiodic, and/or scheduled or unscheduled.

The communication circuitry 116 may include signal-construction circuitry including, but not limited to, an encoder to encode input data, and a modulator to modulate a carrier signal to include the encoded input data to be transmitted. The communication circuitry 116 may further include signal-deconstruction circuitry including, but not limited to, a demodulator to provide encoded data from a modulated carrier signal, and a decoder to provide data from encoded data.

The radio transceiver 122 may provide for the transmission and reception of the RF signals. The radio transceiver 122 may have RF transmit circuitry such as, but not limited to, an up-converter to convert baseband signals to radio-frequency signals, and a power amplifier (PA) to amplify the RF signals for transmission. The radio transceiver 122 may further have RF receive circuitry such as, but not limited to, a low-noise amplifier to amplify a received RF signal, a filter to filter a received RF signal, and a downconverter to convert an RF signal to a baseband signal. The control circuitry 120 may be coupled to communication circuitry 116, and may be configured to perform higher layer operations, for example, operations at layers in a communication protocol stack that are higher than

layers of the communication protocol stack that perform the operations of the communication circuitry 116 for the radio transceiver 122.

In some embodiments, the communication circuitry 116 and the control circuitry 120 may, collectively, provide the majority or all of the operations related to the communication protocol stack. The communication circuitry 116 and the control circuitry 120 may include, or be a part of, baseband circuitry (for example, a baseband chipset), a PC card, a connect card, a mobile broadband modem, etc.

The eNB 108 may include communication circuitry 128 to interface with radio transceiver 132 to communicate over the air interface to, for example, receive uplink RF signals from UE 104 via one or more antennas 136 and transmit downlink RF signals to UE 104 via the one or more antennas 136. In some embodiments, the communication circuitry 128 may have signal-construction circuitry and signal-deconstruction circuitry that complement the corresponding circuitry in communication circuitry 116. Similarly, the transceiver 132 may include RF transmit circuitry and RF receive circuitry that complement the corresponding circuitry in radio transceiver 122.

The eNB 108 may also include control circuitry 140 coupled with communication circuitry 128. The control circuitry 140 may be configured to perform higher layer operations to control aspects of wireless communications in the cell provided by the eNB 108.

In addition to communication over the air interface, the components of the UE 104 and eNB 108 may include circuitry to communicate over one or more additional wired or wireless interfaces. For example, in some embodiments, the transceiver 132 may include an Ethernet interface to support S1-AP signaling over Ethernet networks such as, but not limited to, fiber-optic gigabit and 10 Gigabit Ethernet, to provide the S1-MME interface.

Fig. 2 is a flowchart 200 describing operations of identifying MTC data in accordance with some embodiments.

At 202, the eNB may assign a first frequency offset to a first machine-type communication (MTC) user equipment (UE). The first frequency offset may be with respect to a first transmission resource, which may include a first radio frequency.

At 204, the eNB may assign a second frequency offset to a second MTC UE. The second frequency offset may be with respect to the first transmission resource, which may include the first radio frequency.

At 206, the eNB may receive plural repeated bursts of first MTC data from the first MTC UE over the transmission resource with a first phase shift between the plural

repeated bursts based upon the first frequency offset and plural repeated bursts of second MTC data from the second MTC UE over the transmission resource with a second phase shift between the plural repeated bursts based upon the second frequency offset.

At 208, the eNB may compensate for the first phase shift to identify the first MTC data from the first MTC UE. In an embodiment, the eNB compensating for the first phase shift may include applying a first compensation to the plural repeated bursts of the first MTC data, wherein the first compensation may provide constructive superposition of the plural repeated bursts of the first MTC data. In an embodiment, the first compensation may also provide destructive superposition of the plural repeated bursts of the second MTC data with the second phase shift.

At 210, the eNB may compensate for the second phase shift to identify the second MTC data from the second MTC UE. In an embodiment, the eNB compensating for the second phase shift may include applying a second compensation to the plural repeated bursts of the second MTC data, wherein the second compensation may provide constructive superposition of the plural repeated bursts of the second MTC data. In an embodiment, the second compensation may also provide destructive superposition of the plural repeated bursts of the first MTC data with the first phase shift.

The operations of identifying MTC data in accordance with some embodiments of flowchart 200 may be applied to more than two MTC UEs. As an illustration of embodiments, the following describes operations of identifying MTC data that may be provided by four MTC UEs, for example. The illustration may refer to the environment 100 of Fig. 1 and aspects of, for example, a GSM cellular standard that may include a 200 kHz bandwidth with a GMSK (Gaussian Minimum Shift Keying) modulation scheme with a gross channel rate of 1625/6 kbps (270.8333 kbps), an 8-time slot TDMA frame of 60/13 mS, which may provide for each time slot 625/4 or 156.25 bits over a period of 15/26 or 0.5769 mS. In embodiments, other cellular standards or modulation schemes may be applied.

As described at 202 and 204, frequency offsets may be applied to first and second MTC UE 104, respectively. In accordance with this illustration, four frequency offsets may be applied to four MTC UEs 104, which may be referred to as MTCUE1-MTCUE4. For example, frequency offsets of -866 Hz, -433 Hz, 0 Hz and 433 Hz may be applied to MTCUE1, MTCUE2, MTCUE3, MTCUE4, respectively.

As described at 206, the eNB 108 may receive plural repeated bursts of first MTC data from the first MTC UE 104 over the transmission resource with a first phase shift

between the plural repeated bursts based upon the first frequency offset. In an embodiment of this illustration, with a frequency offset of 866 Hz in bursts of MTC data from MTCUE1 over a TDMA time slot of 156.25 bits, the eNB may receive bursts of MTC data from MTCUE1 with a phase shift $\Delta\phi_1$ of $-\pi$, which may be calculated as:

5

$$\Delta\phi_1 = 2\pi * (-866) * 156.25/270833 \approx -\pi$$

As described at 208, the eNB 108 may receive plural repeated bursts of second MTC data from the second MTC UE 104 over the transmission resource with a second phase shift. Similarly, with frequency offsets of -433 Hz, 0 Hz and 433 in bursts of MTC data from MTCUE2-MTCUE4 over TDMA time slots of 156.25 bits, the eNB 108 may receive bursts of MTC data from MTCUE2-MTCUE4 with phase shifts $\Delta\phi_2$ - $\Delta\phi_4$ of $-\frac{\pi}{2}$, 0 , $\frac{\pi}{2}$, respectively:

10

$$\Delta\phi_2 = 2\pi * (-433) * 156.25/270833 \approx -\pi/2$$

15

$$\Delta\phi_3 = 2\pi * (0) * 156.25/270833 \approx 0$$

$$\Delta\phi_4 = 2\pi * (433) * 156.25/270833 \approx \pi/2$$

20

In embodiments, this illustration may include four repeated bursts of MTC data from MTCUE1-MTCUE4 with phase shift. The four repeated bursts of MTC data may be provided over four successive TDMA time slots, as summarized in Table 1, in which the four successive TDMA time slots are indicated by the term “Burst Index”:

Table 1 - MTCUE1-MTCUE4 with Phase Shift

<i>Burst index</i> <i>Device</i>	<i>1</i>	<i>2</i>	<i>3</i>	<i>4</i>
<i>MTCUE 1</i>	ϕ_0	$\phi_0 - \pi$	$\phi_0 - 2\pi$	$\phi_0 - 3\pi$
<i>MTCUE 2</i>	ϕ_0	$\phi_0 - \frac{\pi}{2}$	$\phi_0 - \pi$	$\phi_0 - \frac{3\pi}{2}$
<i>MTCUE 3</i>	ϕ_0	ϕ_0	ϕ_0	ϕ_0
<i>MTCUE 4</i>	ϕ_0	$\phi_0 + \frac{\pi}{2}$	$\phi_0 + \pi$	$\phi_0 + \frac{3\pi}{2}$

The phase shift may include applying a controlled phase difference to one or more repeated bursts of MTC data from one or more of the MTC UE 104 and/or applying different phase differences to MTC data from different MTCUE 104. In this illustration, the first bursts of MTC data from MTCUE1-MTCUE4 may have the same phase, with phase differences arising over successive bursts or time slots providing phase shift between the MTC data. Phase shift between the MTC data from the different MTCUE may arise by application of phase shifts of different amounts, which may include zero phase shift as illustrated by MTCUE3.

As described at 210, the eNB 108 may compensate for the first phase shift to identify the first MTC data from the first MTC UE 104. In an embodiment of this illustration, eNB 108 may compensate for the phase shift of MTCUE1 to identify the MTC data from MTCUE1 by applying a compensating phase offset to each burst or time slot with a phase difference from a preceding burst or time slot. In this illustration, the compensating phase offset may be π to compensate for a phase shift of $-\pi$ applied to subsequent bursts of MTC data from MTCUE1. Table 2 shows an embodiment of a compensating phase offset of π applied to each subsequent burst or time slot with a phase difference from a preceding burst or time slot:

Table 2 - MTCUE1-MTCUE4 with Compensating Phase Offset for MTCUE1

<i>Burst index</i> <i>Device</i>	1	2	3	4
<i>MTCUE 1</i>	ϕ_0	ϕ_0	ϕ_0	ϕ_0
<i>MTCUE 2</i>	ϕ_0	$\phi_0 + \frac{\pi}{2}$	$\phi_0 + \pi$	$\phi_0 + \frac{3\pi}{2}$
<i>MTCUE 3</i>	ϕ_0	$\phi_0 + \pi$	$\phi_0 + 2\pi$	$\phi_0 + 3\pi$
<i>MTCUE 4</i>	ϕ_0	$\phi_0 + \frac{3\pi}{2}$	$\phi_0 + 3\pi$	$\phi_0 + \frac{9\pi}{2}$

With application of the compensating phase offset of π for the MTC data from MTCUE1, the eNB 108 may compensate for the phase shift of the MTC data from

MTCUE1 to provide constructive superposition of the plural repeated bursts of the MTC data from MTCUE1 and to identify the MTC data from MTCUE1. In an embodiment, the compensating phase offset of π for the MTC data from MTCUE1 may also provide destructive superposition of the four repeated bursts of the MTC data from each of

5 MTCUE2- MTCUE4.

As described at 212, the eNB may compensate for the second phase shift to identify the second MTC data from the second MTC UE. In an embodiment of this illustration, the eNB may successively compensate for the phase shift of each of MTCUE2- MTCUE4 to identify the MTC data from each of MTCUE2- MTCUE4 by

10 applying corresponding compensating phase offsets. In this illustration, the compensating phase offsets may be $\pi/2$, 0, and $-\pi/2$ to compensate for the phase shifts of $-\pi/2$, 0, and $\pi/2$ applied to subsequent bursts of MTC data from MTCUE2, MTCUE3, MTCUE4, respectively. Tables 3, 4, and 5 show embodiments of compensating phase offsets of $-\pi/2$, 0, and $\pi/2$ applied to each subsequent burst or time slot with a phase difference
15 from a preceding burst or time slot:

Table 3 - MTCUE1-MTCUE4 with Compensating Phase Offset for MTCUE2

<i>Burst index</i> <i>Device</i>	<i>1</i>	<i>2</i>	<i>3</i>	<i>4</i>
<i>MTCUE 1</i>	ϕ_0	$\phi_0 - \frac{\pi}{2}$	$\phi_0 - \pi$	$\phi_0 - \frac{3\pi}{2}$
<i>MTCUE 2</i>	ϕ_0	ϕ_0	ϕ_0	ϕ_0
<i>MTCUE 3</i>	ϕ_0	$\phi_0 + \frac{\pi}{2}$	$\phi_0 + \pi$	$\phi_0 + \frac{3\pi}{2}$
<i>MTCUE 4</i>	ϕ_0	$\phi_0 + \pi$	$\phi_0 + 2\pi$	$\phi_0 + 3\pi$

5 Table 4 - MTCUE1-MTCUE4 with Compensating Phase Offset for MTCUE3

<i>Burst index</i> <i>Device</i>	<i>1</i>	<i>2</i>	<i>3</i>	<i>4</i>
<i>MTCUE 1</i>	ϕ_0	$\phi_0 - \pi$	$\phi_0 - 2\pi$	$\phi_0 - 3\pi$
<i>MTCUE 2</i>	ϕ_0	$\phi_0 - \frac{\pi}{2}$	$\phi_0 - \pi$	$\phi_0 - \frac{3\pi}{2}$
<i>MTCUE 3</i>	ϕ_0	ϕ_0	ϕ_0	ϕ_0
<i>MTCUE 4</i>	ϕ_0	$\phi_0 + \frac{\pi}{2}$	$\phi_0 + \pi$	$\phi_0 + \frac{3\pi}{2}$

Table 5 - MTCUE1-MTCUE4 with Compensating Phase Offset for MTCUE4

<i>Burst index</i> <i>Device</i>	<i>1</i>	<i>2</i>	<i>3</i>	<i>4</i>
<i>MTCUE 1</i>	ϕ_0	$\phi_0 - \frac{3\pi}{2}$	$\phi_0 - 3\pi$	$\phi_0 - \frac{9\pi}{2}$
<i>MTCUE 2</i>	ϕ_0	$\phi_0 - \pi$	$\phi_0 - 2\pi$	$\phi_0 - 3\pi$
<i>MTCUE 3</i>	ϕ_0	$\phi_0 - \frac{\pi}{2}$	$\phi_0 - \pi$	$\phi_0 - \frac{3\pi}{2}$
<i>MTCUE 4</i>	ϕ_0	ϕ_0	ϕ_0	ϕ_0

Tables 2-5 illustrate embodiments in which MTC data from MTC UE 1-4 may be successively identified over four successive bursts of four time slots each. In embodiments, the four successive bursts of four time slots each may occur over at least two TDMA frames. With each burst, the eNB 108 may apply a compensating phase offset to identify the MTC data from a corresponding one of the MTC UE 1-4. As illustrated, identifying MTC data from MTC UE 1-4 may include applying a complex conjugate phase rotation successively and combining or adding the corresponding samples of the received bursts to achieve constructive superposition of the MTC data from each MTC UE individually while the other MTC UE undergo destructive superposition.

Fig. 3 is a flowchart 300 describing operations of identifying MTC data in accordance with some embodiments. The operations described in Fig. 3 may be performed by the eNB 108 in accordance with some embodiments.

At 302, the eNB may assign frequency offsets to one or more of plural machine-type communication (MTC) user equipment (UE).

At 304, the eNB may receive plural repeated bursts of MTC data from each of the plural MTC UE over a shared transmission resource with phase shift between the plural repeated bursts based upon the frequency offsets. The shared transmission resource may include a shared radio frequency or channel and/or a shared time period.

At 306, the eNB may compensate for the phase shift to identify the MTC data corresponding to each of the plural the MTC UE.

In embodiments described above, bursts of MTC data may be of generally equal lengths of 156.25 bits each, for example, and a common frequency offset for the multiple bursts of MTC data from each MTCUE may be applied. For example, frequency offsets of -866 Hz, -433 Hz, 0 Hz and 433 may be applied for MTCUE1, MTCUE2, MTCUE3, and MTCUE4, respectively, to provide corresponding phase differences.

In other embodiments, bursts of MTC data may be of different lengths. For example, in an embodiment, MTC data bursts 1, 2, 3, and 4 may include 157 bits, 156 bits, 156 bits, and 156 bits, respectively. In such an embodiment, different frequency offsets may be applied in relation to the number of bits in a data burst. Table 6 lists frequency offsets that may be applied to MTCUE1, MTCUE2, MTCUE3, and MTCUE4 in an embodiment in which data bursts 1, 2, 3, and 4 may include 157 bits, 156 bits, 156 bits, and 156 bits, respectively. The frequency offsets of Table 6 may provide a phase shift substantially similar to the phase shift of Table 1, and in embodiments may be applied in connection with the operations of Figs. 2 or 3, for example

Table 6 - MTCUE1-MTCUE4 Frequency Offsets (Hz)

<i>Burst index</i> <i>Device</i>	<i>1</i> <i>(157 bits)</i>	<i>2</i> <i>(156 bits)</i>	<i>3</i> <i>(156 bits)</i>	<i>4</i> <i>(156 bits)</i>
<i>MTCUE 1</i>	-862	-868	-868	-868
<i>MTCUE 2</i>	-431	-434	-434	-434 20
<i>MTCUE 3</i>	0	0	0	0
<i>MTCUE 4</i>	431	434	434	434

As an illustration, the phase offsets that may be provided for burst index 1 of 157 bits by the listed frequency offsets may be:

$$\Delta\phi_1' = 2\pi * (-862) * 157/270833 \approx -\pi$$

$$\Delta\phi_2' = 2\pi * (-431) * 156/270833 \approx -\pi/2$$

$$\Delta\phi_3' = 2\pi * (0) * 156/270833 \approx 0$$

$$\Delta\phi_4' = 2\pi * (431) * 156/270833 \approx \pi/2$$

In embodiments, the operations of Figs. 2 and 3 may operate as an overlaid code division multiple access (CDMA) technique that may increase uplink (UL) capacity from the multiple MTC UEs 104 to the eNB 108. This may allow multiplexing of multiple MTC UEs 104 simultaneously on a shared physical resource, for example, same time slot and same arbitrary radio frequency.

Overlaid CDMA operation may include the eNB 108 specifying different orthogonal codes to be applied by each of plural MT CUE 104, and the eNB 108 compensating for the different orthogonal in succession further to identify the MTC data from each MT CUE 104. In embodiments, the eNB 108 may specify different Hadamard codes to be assigned to the different MTC UE 104, such as MTCUE1-MTCUE4. To identify the MTC data from each MTC UE, the eNB 108 may first correlate the MTC data with the Hadamard code of the corresponding MTC UE on a burst level and then coherently add the received signal. Due to the orthogonal property of Hadamard code, the signal from the other three users may be canceled by destructive superposition.

Effective operation of the overlaid CDMA using GMSK/8PSK modulation, previously inhibited by inability to manipulate phase of synthesizer/phase lock loop of CIoT devices, may be facilitated by the addition and subsequent compensation of the phase shifts as described herein.

In connection with other embodiments, Fig. 4 is an illustration of a burst 400 in an EC-GSM system employing GMSK modulation that may include 156 bit periods or bits, for example. (An EC-GSM system employing GMSK modulation may alternatively include 157 bit periods or bits, for example.) Burst 400 may include a data segment 402 of 142 data and training sequence code (TSC) bits, designated $x_0, x_1, \dots, x_{141}$, which may be bounded by tail segments 404 and 406 of 3 tail bits each, and tail segments 404, 406 may be bounded by respective guard segments 408, 410 of 4 guard or dummy bits each. The guard or dummy bits of guard segments 406 may be used to fill gaps between burst transmissions and may be distinct from the data and TSC bits of data segment 402 and the tail bits of tail segments 404.

Fig. 5 is a flowchart 500 describing operations of identifying MTC data in accordance with some embodiments.

At 502, the eNB may assign a first guard bit offset to a first machine-type communication (MTC) user equipment (UE). The first guard bit offset may change a number of guard bits in either of guard segments 406 in a burst transmitted from the first MTC UE.

At 504, the eNB may assign a second guard bit offset to a second machine-type communication (MTC) user equipment (UE). The second guard bit offset may be different from the first guard bit offset and may change a number of guard bits in either of guard segments 406 in a burst transmitted from the second MTC UE.

5 At 506, the eNB may receive plural repeated bursts of first MTC data from the first MTC UE over the transmission resource with a first phase shift between the plural repeated bursts based upon the first guard bit offset.

At 508, the eNB may receive plural repeated bursts of second MTC data from the second MTC UE over the transmission resource with a second phase shift between the plural repeated bursts based upon the second guard bit offset. The second phase shift may be different from the first phase shift.

At 510, the eNB may compensate for the first phase shift to identify the first MTC data from the first MTC UE. In an embodiment, the eNB compensating for the first phase shift may include applying a first compensation to the plural repeated bursts of the first MTC data, wherein the first compensation may provide constructive superposition of the plural repeated bursts of the first MTC data. In an embodiment, the first compensation may also provide destructive superposition of the plural repeated bursts of the second MTC data with the second phase shift.

At 512 the eNB may compensate for the second phase shift to identify the second MTC data from the second MTC UE. In an embodiment, the eNB compensating for the second phase shift may include applying a second compensation to the plural repeated bursts of the second MTC data, wherein the second compensation may provide constructive superposition of the plural repeated bursts of the second MTC data. In an embodiment, the second compensation may also provide destructive superposition of the plural repeated bursts of the first MTC data with the first phase shift.

An aspect of embodiments of the operations of flowchart 500 is that each added or subtracted guard bit may result in or effect a phase change of $\pi/2$ or $-\pi/2$ for a burst or a next successive burst, respectively. In embodiments, adding or subtracting n-number of guard bits may result in or effect a phase change of $n\pi/2$ or $-n\pi/2$, respectively

30 Fig. 6 is an illustration of a burst 600 that is analogous to burst 400 of Fig. 4, and may include data segment 602 of data and training sequence code (TSC) bits, and tail segments 604 and 606. Burst 600 may include a following guard segment 610, and may also include a modified leading guard segment 612, which may include n-number of added

leading bits 614 (e.g., only one shown), to impart a phase shift of $n\pi/2$. In the illustrated embodiment, the one added leading bit 614 imparts a phase shift of $\pi/2$ to burst 600 and, more particularly, to data segment 602.

Fig. 7 is an illustration of a burst 700 that is analogous to burst 400 of Fig. 4, and may include data segment 702 of data and training sequence code (TSC) bits, and tail segments 704 and 706. Burst 700 may include a leading guard segment 708, and may also include a modified following guard segment 710, which may include n-number of added following bits 712 (e.g., only one shown), to impart a phase shift of $n\pi/2$. In the illustrated embodiment, the one added following bit 712 imparts a phase shift of $\pi/2$ to a next successive burst 714 (partly shown) and, more particularly, its data segment (not shown).

Fig. 8 is an illustration of a burst 800 that is analogous to burst 400 of Fig. 4, and may include data segment 802 of data and training sequence code (TSC) bits, and tail segments 804 and 806. Burst 800 may include a following guard segment 810 and a modified leading guard segment 812, which may not include n-number of deleted guard bits 814 (e.g., only one deleted bit shown, designated X), to impart a phase shift of $-n\pi/2$. In the illustrated embodiment, the one deleted leading bit 814 imparts a phase shift of $-\pi/2$ to burst 800 and, more particularly, to data segment 802.

Fig. 9 is an illustration of a burst 900 that is analogous to burst 400 of Fig. 4, and may include data segment 902 of data and training sequence code (TSC) bits, and tail segments 904 and 906. Burst 900 may include a leading guard segment 908, and may also include a modified following guard segment 910, which may include n-number of deleted following bits 912 (e.g., only one deleted bit shown, designated X), to impart a phase shift of $-n\pi/2$. In the illustrated embodiment, the one added following bit 912 imparts a phase shift of $-\pi/2$ to a next successive burst 914 (partly shown) and, more particularly, its data segment (not shown).

As described above with reference to Table 1, phase shifts of $-\pi, -\frac{\pi}{2}, 0, \frac{\pi}{2}$, assigned by a eNB 108 among four MTC UE 104, may provide phase shift between the four MTC UE 104 by which MTC data from the four MTC UE 104 may be identified by the eNB 108 successively over repeated bursts of the MTC data, as described above. Figs. 6 and 7 illustrate guard bit offsets that may generate positive phase shifts of $n\pi/2$ for a frame (e.g., burst 600) or a next succeeding burst (e.g., burst 714) for n-number of added guard bits. Figs. 8 and 9 illustrate guard bit offsets that may generate negative phase shifts

of $-\pi/2$ for a burst (e.g., burst 800) or a next succeeding burst (e.g., burst 914) for n-number of added guard bits. Negative phase shifts of $-\pi$ and $-\frac{\pi}{2}$ may be obtained with guard bit offsets of two bits and one bit, respectively. Non-negative phase shifts of 0 and $\frac{\pi}{2}$ may be obtained with guard bit offsets of zero bits and one bit, respectively.

5 Fig. 10 is a flowchart 1000 describing operations of identifying MTC data in accordance with some embodiments. The operations described in Fig. 10 may be performed by the MTC UE 104 in accordance with some embodiments.

At 1002, the MTC UE may receive a frequency offset from, for example, an eNB 108. In embodiments, the frequency offset may be with respect to a shared radio frequency
10 that the MTC UE shares with multiple other MTC UEs as a shared transmission resource.

At 1004, the MTC UE may transmit a first burst of MTC data over the shared transmission resource with the frequency offset from the shared radio frequency.

At 1006, the MTC UE may transmit a second burst of MTC data over the shared transmission resource with the frequency offset from the shared radio frequency.

15 Operation 1006 may return to operation 1004. In embodiments, the frequency offset may impart between the first and second bursts of MTC data of the MTC UE a phase shift from which the MTC data of the MTC UE may be identified from other MTC data on the shared transmission resource.

As used herein, the term "circuitry" may refer to, be part of, or include
20 an Application Specific Integrated Circuit (ASIC), an electronic circuit, a processor (shared, dedicated, or group), and/or memory (shared, dedicated, or group) that execute one or more software or firmware programs, a combinational logic circuit, and/or other suitable hardware components that provide the described functionality. In some embodiments, the circuitry may be implemented in, or functions associated with the
25 circuitry may be implemented by, one or more software or firmware modules. In some embodiments, circuitry may include logic, at least partially operable in hardware.

Embodiments described herein may be implemented into a system using any suitably configured hardware and/or software. Fig. 11 illustrates, for one embodiment, example components of an electronic device 1100. In embodiments, the electronic device
30 1100 may be, implement, be incorporated into, or otherwise be a part of a user equipment (UE), an evolved NodeB (eNB), or some other suitable electronic device. In some embodiments, the electronic device 1100 may include application circuitry 1102, baseband

circuitry 1104, Radio Frequency (RF) circuitry 1106, front-end module (FEM) circuitry 1108 and one or more antennas 1110, coupled together at least as shown.

The application circuitry 1102 may include one or more application processors. For example, the application circuitry 1102 may include circuitry such as, but not limited to, one or more single-core or multi-core processors. The processor(s) may include any combination of general-purpose processors and dedicated processors (e.g., graphics processors, application processors, etc.). The processors may be coupled with and/or may include memory/storage and may be configured to execute instructions stored in the memory/storage to enable various applications and/or operating systems to run on the system.

The baseband circuitry 1104 may include circuitry such as, but not limited to, one or more single-core or multi-core processors. The baseband circuitry 1104 may include one or more baseband processors and/or control logic to process baseband signals received from a receive signal path of the RF circuitry 1106 and to generate baseband signals for a transmit signal path of the RF circuitry 1106. Baseband processing circuitry 1104 may interface with the application circuitry 1102 for generation and processing of the baseband signals and for controlling operations of the RF circuitry 1106. For example, in some embodiments, the baseband circuitry 1104 may include a second generation (2G) baseband processor 1104a, third generation (3G) baseband processor 1104b, fourth generation (4G) baseband processor 1104c, and/or other baseband processor(s) 1104d for other existing generations, generations in development or to be developed in the future (e.g., fifth generation (5G), 6G, etc.). The baseband circuitry 1104 (e.g., one or more of baseband processors 1104a-d) may handle various radio control functions that enable communication with one or more radio networks via the RF circuitry 1106. The radio control functions may include, but are not limited to, signal modulation/demodulation, encoding/decoding, radio frequency shifting, etc. In some embodiments, modulation/demodulation circuitry of the baseband circuitry 1104 may include Fast-Fourier Transform (FFT), precoding, and/or constellation mapping/demapping functionality. In some embodiments, encoding/decoding circuitry of the baseband circuitry 1104 may include convolution, tail-biting convolution, turbo, Viterbi, and/or Low Density Parity Check (LDPC) encoder/decoder functionality. Embodiments of modulation/demodulation and encoder/decoder functionality are not limited to these examples and may include other suitable functionality in other embodiments.

In some embodiments, the baseband circuitry 1104 may include elements of a protocol stack such as, for example, elements of an evolved universal terrestrial radio access network (EUTRAN) protocol including, for example, physical (PHY), media access control (MAC), radio link control (RLC), packet data convergence protocol (PDCP), and/or radio resource control (RRC) elements. A central processing unit (CPU) 1104e of the baseband circuitry 1104 may be configured to run elements of the protocol stack for signaling of the PHY, MAC, RLC, PDCP and/or RRC layers. In some embodiments, the baseband circuitry may include one or more audio digital signal processor(s) (DSP) 1104f. The audio DSP(s) 1104f may include elements for compression/decompression and echo cancellation and may include other suitable processing elements in other embodiments.

The baseband circuitry 1104 may further include memory/storage 1104g. The memory/storage 1104g may be used to load and store data and/or instructions for operations performed by the processors of the baseband circuitry 1104. Memory/storage for one embodiment may include any combination of suitable volatile memory and/or non-volatile memory. The memory/storage 1104g may include any combination of various levels of memory/storage including, but not limited to, read-only memory (ROM) having embedded software instructions (e.g., firmware), random access memory (e.g., dynamic random access memory (DRAM)), cache, buffers, etc. The memory/storage 1104g may be shared among the various processors or dedicated to particular processors.

Components of the baseband circuitry may be suitably combined in a single chip, a single chipset, or disposed on a same circuit board in some embodiments. In some embodiments, some or all of the constituent components of the baseband circuitry 1104 and the application circuitry 1102 may be implemented together such as, for example, on a system on a chip (SOC).

In some embodiments, the baseband circuitry 1104 may provide for communication compatible with one or more radio technologies. For example, in some embodiments, the baseband circuitry 1104 may support communication with an evolved universal terrestrial radio access network (EUTRAN) and/or other wireless metropolitan area networks (WMAN), a wireless local area network (WLAN), a wireless personal area network (WPAN). Embodiments in which the baseband circuitry 1104 is configured to support radio communications of more than one wireless protocol may be referred to as multi-mode baseband circuitry.

RF circuitry 1106 may enable communication with wireless networks using modulated electromagnetic radiation through a non-solid medium. In various embodiments, the RF circuitry 1106 may include switches, filters, amplifiers, etc. to facilitate the communication with the wireless network. RF circuitry 1106 may include a receive signal path which may include circuitry to down-convert RF signals received from the FEM circuitry 1108 and provide baseband signals to the baseband circuitry 1104. RF circuitry 1106 may also include a transmit signal path which may include circuitry to up-convert baseband signals provided by the baseband circuitry 1104 and provide RF output signals to the FEM circuitry 1108 for transmission.

In some embodiments, the RF circuitry 1106 may include a receive signal path and a transmit signal path. The receive signal path of the RF circuitry 1106 may include mixer circuitry 1106a, amplifier circuitry 1106b and filter circuitry 1106c. The transmit signal path of the RF circuitry 1106 may include filter circuitry 1106c and mixer circuitry 1106a. RF circuitry 1106 may also include synthesizer circuitry 1106d for synthesizing a frequency for use by the mixer circuitry 1106a of the receive signal path and the transmit signal path. In some embodiments, the mixer circuitry 1106a of the receive signal path may be configured to down-convert RF signals received from the FEM circuitry 1108 based on the synthesized frequency provided by synthesizer circuitry 1106d. The amplifier circuitry 1106b may be configured to amplify the down-converted signals and the filter circuitry 1106c may be a low-pass filter (LPF) or band-pass filter (BPF) configured to remove unwanted signals from the down-converted signals to generate output baseband signals. Output baseband signals may be provided to the baseband circuitry 1104 for further processing. In some embodiments, the output baseband signals may be zero-frequency baseband signals, although this is not a requirement. In some embodiments, mixer circuitry 1106a of the receive signal path may comprise passive mixers, although the scope of the embodiments is not limited in this respect.

In some embodiments, the mixer circuitry 1106a of the transmit signal path may be configured to up-convert input baseband signals based on the synthesized frequency provided by the synthesizer circuitry 1106d to generate RF output signals for the FEM circuitry 1108. The baseband signals may be provided by the baseband circuitry 1104 and may be filtered by filter circuitry 1106c. The filter circuitry 1106c may include a low-pass filter (LPF), although the scope of the embodiments is not limited in this respect.

In some embodiments, the mixer circuitry 1106a of the receive signal path and the mixer circuitry 1106a of the transmit signal path may include two or more mixers and may

be arranged for quadrature downconversion and/or upconversion respectively. In some embodiments, the mixer circuitry 1106a of the receive signal path and the mixer circuitry 1106a of the transmit signal path may include two or more mixers and may be arranged for image rejection (e.g., Hartley image rejection). In some embodiments, the mixer circuitry 1106a of the receive signal path and the mixer circuitry 1106a may be arranged for direct downconversion and/or direct upconversion, respectively. In some embodiments, the mixer circuitry 1106a of the receive signal path and the mixer circuitry 1106a of the transmit signal path may be configured for super-heterodyne operation.

In some embodiments, the output baseband signals and the input baseband signals may be analog baseband signals, although the scope of the embodiments is not limited in this respect. In some alternate embodiments, the output baseband signals and the input baseband signals may be digital baseband signals. In these alternate embodiments, the RF circuitry 1106 may include analog-to-digital converter (ADC) and digital-to-analog converter (DAC) circuitry and the baseband circuitry 1104 may include a digital baseband interface to communicate with the RF circuitry 1106.

In some dual-mode embodiments, a separate radio IC circuitry may be provided for processing signals for each spectrum, although the scope of the embodiments is not limited in this respect.

In some embodiments, the synthesizer circuitry 1106d may be a fractional-N synthesizer or a fractional $N/N+1$ synthesizer, although the scope of the embodiments is not limited in this respect as other types of frequency synthesizers may be suitable. For example, synthesizer circuitry 1106d may be a delta-sigma synthesizer, a frequency multiplier, or a synthesizer comprising a phase-locked loop with a frequency divider.

The synthesizer circuitry 1106d may be configured to synthesize an output frequency for use by the mixer circuitry 1106a of the RF circuitry 1106 based on a frequency input and a divider control input. In some embodiments, the synthesizer circuitry 1106d may be a fractional $N/N+1$ synthesizer.

In some embodiments, frequency input may be provided by a voltage controlled oscillator (VCO), although that is not a requirement. Divider control input may be provided by either the baseband circuitry 1104 or the applications processor 1102 depending on the desired output frequency. In some embodiments, a divider control input (e.g., N) may be determined from a look-up table based on a channel indicated by the applications processor 1102.

Synthesizer circuitry 1106d of the RF circuitry 1106 may include a divider, a delay-locked loop (DLL), a multiplexer and a phase accumulator. In some embodiments, the divider may be a dual modulus divider (DMD) and the phase accumulator may be a digital phase accumulator (DPA). In some embodiments, the DMD may be configured to
5 divide the input signal by either N or N+1 (e.g., based on a carry out) to provide a fractional division ratio. In some example embodiments, the DLL may include a set of cascaded, tunable, delay elements, a phase detector, a charge pump and a D-type flip-flop. In these embodiments, the delay elements may be configured to break a VCO period up into Nd equal packets of phase, where Nd is the number of delay elements in the delay
10 line. In this way, the DLL provides negative feedback to help ensure that the total delay through the delay line is one VCO cycle.

In some embodiments, synthesizer circuitry 1106d may be configured to generate a carrier frequency as the output frequency, while in other embodiments, the output frequency may be a multiple of the carrier frequency (e.g., twice the carrier frequency,
15 four times the carrier frequency) and used in conjunction with quadrature generator and divider circuitry to generate multiple signals at the carrier frequency with multiple different phases with respect to each other. In some embodiments, the output frequency may be a LO frequency (fLO). In some embodiments, the RF circuitry 1106 may include an IQ/polar converter.

FEM circuitry 1108 may include a receive signal path which may include circuitry
20 configured to operate on RF signals received from one or more antennas 1110, amplify the received signals and provide the amplified versions of the received signals to the RF circuitry 1106 for further processing. FEM circuitry 1108 may also include a transmit signal path which may include circuitry configured to amplify signals for transmission
25 provided by the RF circuitry 1106 for transmission by one or more of the one or more antennas 1110.

In some embodiments, the FEM circuitry 1108 may include a TX/RX switch to switch between transmit mode and receive mode operation. The FEM circuitry may include a receive signal path and a transmit signal path. The receive signal path of the
30 FEM circuitry may include a low-noise amplifier (LNA) to amplify received RF signals and provide the amplified received RF signals as an output (e.g., to the RF circuitry 1106). The transmit signal path of the FEM circuitry 1108 may include a power amplifier (PA) to amplify input RF signals (e.g., provided by RF circuitry 1106), and one or more filters to

generate RF signals for subsequent transmission (e.g., by one or more of the one or more antennas 1110.

In some embodiments, the electronic device 1100 may include additional elements such as, for example, memory/storage, display, camera, sensor, and/or input/output (I/O) interface.

In some embodiments, the electronic device 1100 may be configured to perform one or more methods, processes, and/or techniques, or one or more portions thereof, as described herein.

Some non-limiting examples are provided below.

Example 1 may include one or more computer-readable media having instructions that, when executed, cause an evolved node B (eNB) to assign frequency offsets to one or more of plural machine-type communication (MTC) user equipment (UE) that are to communicate with the eNB over a shared transmission resource, which includes a shared radio frequency, using code-division multiple access (CDMA); receive plural repeated bursts of MTC data from a first MTC UE of the plural MTC UEs over the shared transmission resource with a first phase shift based upon the frequency offset assigned to the first MTC UE; and compensate for the first phase shift to identify the MTC data corresponding to the first MTC UE.

Example 2 may include the one or more computer-readable media of example 1 and/or any other example described herein, wherein the instructions, when executed, further cause the eNB to receive plural repeated bursts of MTC data from a second MTC UE of the plural MTC UEs over the shared transmission resource with a second phase shift based upon the frequency offset assigned to the second MTC UE; and compensate for the phase shift to identify the MTC data corresponding to the second MTC UE.

Example 3 may include the one or more computer-readable media of example 2 and/or any other example described herein, wherein the instructions, when executed, further cause the eNB to compensate for the first and second phase shifts to identify the MTC data corresponding to the respective first and second MTC UEs successively.

Example 4 may include the one or more computer-readable media of example 2 and/or any other example described herein, wherein the instructions, when executed, further cause the eNB to assign first and second orthogonal codes to the respective first and second MTC UEs; receive the plural repeated bursts of MTC data from the first and second MTC UEs further with application of the orthogonal codes; and decode the

orthogonal codes further to identify the MTC data corresponding to the first and second MTC UEs.

Example 5 may include the one or more computer-readable media of example 4 and/or any other example described herein, wherein the orthogonal codes further include
5 Hadamard codes.

Example 6 may include the one or more computer-readable media of example 2 and/or any other example described herein, wherein the instructions, when executed, further cause the eNB to receive the plural repeated bursts of MTC data from the first and second MTC UEs concurrently over a common time period.

10 Example 7 may include the one or more computer-readable media of any of examples 1-6 and/or any other example described herein, wherein the instructions, when executed, further cause the eNB to receive the plural repeated bursts of MTC data from the first MTC UE with at least one of the bursts of MTC data being of a length different from lengths of the other bursts of MTC data.

15 Example 8 may include an apparatus, comprising one or more storage media having instructions; and one or more processors coupled with the one or more storage media to execute the instructions to cause the apparatus to receive from each of plural machine-type communication (MTC) user equipment (UEs) plural repeated bursts of MTC data over a shared transmission resource with a shared radio frequency in which, for each
20 MTC UE, a phase shift is included between each burst of MTC data based upon a frequency offset relative to the shared radio frequency; and identify with respect to the phase shifts the MTC data of each of the MTC UEs.

Example 9 may include the apparatus of example 8 and/or any other example described herein, wherein one or more processors cause the apparatus to for each MTC UE
25 successively, compensate for the phase shift included between each burst of MTC data from the MTC UE to identify the MTC data from the MTC UE.

Example 10 may include the apparatus of example 9 and/or any other example described herein, wherein one or more processors cause the apparatus to compensate for the phase shift included between each burst of MTC data from the MTC UE with
30 constructive superposition of the bursts of MTC data from the MTC UE concurrent with destructive superposition of the bursts of MTC data from the other MTC UEs.

Example 11 may include the apparatus any of examples 8-10 and/or any other example described herein, wherein one or more processors cause the apparatus to assign orthogonal codes to the plural MTC UEs; receive the plural repeated bursts of MTC data

from each of the plural MTC UEs further with application of the orthogonal codes; and decode the orthogonal codes further to identify the MTC data corresponding to each of the plural the MTC UE.

5 Example 12 may include the apparatus of example 11 and/or any other example described herein, wherein the orthogonal codes further include Hadamard codes.

Example 13 may include the apparatus of any of examples 8-10 and/or any other example described herein, wherein one or more processors cause the apparatus to receive the plural bursts of MTC data from at least one of the MTC UEs with one of the bursts of the MTC data from the at least one MTC UE being of a length different from lengths of
10 the other bursts of MTC data from the at least one MTC UE.

Example 14 may include one or more computer-readable media having instructions that, when executed, cause an evolved node B (eNB) to assign guard bit offsets to one or more of plural machine-type communication (MTC) user equipment (UE); receive plural repeated bursts of MTC data from each of the plural MTC UE over a shared transmission
15 resource with phase shift between the plural repeated bursts based upon the guard bit offsets, the shared transmission resource including a shared radio frequency; and compensate for the phase shift to identify the MTC data corresponding to each of the plural the MTC UE.

Example 15 may include the one or more computer-readable media of example 14
20 and/or any other example described herein, wherein the instructions, when executed, further cause the eNB to compensate for the phase shift to identify the MTC data corresponding to each of the plural the MTC UE successively.

Example 16 may include the one or more computer-readable media of example 14 and/or any other example described herein, wherein the instructions, when executed,
25 further cause the eNB to compensate for the phase shift to identify the MTC data corresponding to each of the plural the MTC UE successively with successive constructive superposition of the plural repeated bursts of MTC data from each of the plural MTC UE.

Example 17 may include the one or more computer-readable media of example 14 and/or any other example described herein, wherein the instructions, when executed,
30 further cause the eNB to compensate for the phase shift to identify the MTC data corresponding to each of the plural the MTC UE successively with successive constructive superposition of the plural repeated bursts of MTC data from each of the plural MTC UE concurrent with destructive superposition of the plural repeated bursts of MTC data from each of the other plural MTC UE.

Example 18 may include the one or more computer-readable media of example 14 and/or any other example described herein, wherein the instructions, when executed, further cause the eNB to receive the plural repeated bursts of MTC data from the plural MTC UE concurrently over a common time period.

5 Example 19 may include an apparatus, comprising one or more storage media having instructions; and one or more processors coupled with the one or more storage media to execute the instructions to cause the apparatus to receive a frequency offset with respect to a radio frequency of a shared transmission resource; transmit a first burst of MTC data over the shared transmission resource with the frequency offset from the shared
10 radio frequency; and transmit a second burst of MTC data over the shared transmission resource with the frequency offset from the shared radio frequency.

Example 20 may include the apparatus of example 19 and/or any other example described herein, in which the frequency offset is received from an eNodeB.

Example 21 may include the apparatus of example 19 and/or any other example
15 described herein, in which the first burst of a first length, the second burst is of a second length, and the first and second lengths are different.

Example 22 may include a method, comprising assigning frequency offsets to one or more of plural machine-type communication (MTC) user equipment (UE) that are to communicate with the eNB over a shared transmission resource, which includes a shared
20 radio frequency, using code-division multiple access (CDMA); receiving plural repeated bursts of MTC data from a first MTC UE of the plural MTC UEs over the shared transmission resource with a first phase shift based upon the frequency offset assigned to the first MTC UE; and compensating for the first phase shift to identify the MTC data corresponding to the first MTC UE.

25 Example 23 may include the method of example 22 and/or any other example described herein, further comprising receiving plural repeated bursts of MTC data from a second MTC UE of the plural MTC UEs over the shared transmission resource with a second phase shift based upon the frequency offset assigned to the second MTC UE; and compensating for the phase shift to identify the MTC data corresponding to the second
30 MTC UE.

Example 24 may include the method of example 23 and/or any other example described herein, further comprising compensating for the first and second phase shifts to identify the MTC data corresponding to the respective first and second MTC UEs successively.

Example 25 may include the method of example 23 and/or any other example described herein, further comprising assigning first and second orthogonal codes to the respective first and second MTC UEs; receiving the plural repeated bursts of MTC data from the first and second MTC UEs further with application of the orthogonal codes; and
5 decoding the orthogonal codes further to identify the MTC data corresponding to the first and second MTC UEs.

Example 26 may include the method of example 25 and/or any other example described herein, wherein the orthogonal codes further include Hadamard codes.

Example 27 may include the method of example 23 and/or any other example
10 described herein, further comprising receiving the plural repeated bursts of MTC data from the first and second MTC UEs concurrently over a common time period.

Example 28 may include the method of any of examples 22-27 and/or any other example described herein, further comprising receiving the plural repeated bursts of MTC data from the first MTC UE with at least one of the bursts of MTC data being of a length
15 different from lengths of the other bursts of MTC data.

Example 29 may include a method, comprising an eNodeB (eNB) receiving from each of plural machine-type communication (MTC) user equipment (UEs) plural repeated bursts of MTC data over a shared transmission resource with a shared radio frequency in which, for each MTC UE, a phase shift is included between each burst of MTC data based
20 upon a frequency offset relative to the shared radio frequency ; and the eNB identifying with respect to the phase shifts the MTC data of each of the MTC UEs.

Example 30 may include the method of example 29 and/or any other example described herein, wherein the method for each MTC UE further comprises successively, compensating for the phase shift included between each burst of MTC data from the MTC
25 UE to identify the MTC data from the MTC UE.

Example 31 may include the method of example 30 and/or any other example described herein, further comprising the eNB compensating for the phase shift included between each burst of MTC data from the MTC UE with constructive superposition of the bursts of MTC data from the MTC UE concurrent with destructive superposition of the
30 bursts of MTC data from the other MTC UEs.

Example 32 may include the method of any of examples 29-31 and/or any other example described herein, further comprising the eNB assigning orthogonal codes to the plural MTC UEs; the eNB receiving the plural repeated bursts of MTC data from each of the plural MTC UEs further with application of the orthogonal codes; and the eNB

decoding the orthogonal codes further to identify the MTC data corresponding to each of the plural the MTC UE.

Example 33 may include the method of example 32 and/or any other example described herein, wherein the orthogonal codes further include Hadamard codes.

5 Example 34 may include the method of any of examples 29-31 and/or any other example described herein, further comprising the eNB receiving the plural bursts of MTC data from at least one of the MTC UEs with one of the bursts of the MTC data from the at least one MTC UE being of a length different from lengths of the other bursts of MTC data from the at least one MTC UE.

10 Example 35 may include a method, comprising an eNodeB (eNB) assigning guard bit offsets to one or more of plural machine-type communication (MTC) user equipment (UE); the eNB receiving plural repeated bursts of MTC data from each of the plural MTC UE over a shared transmission resource with phase shift between the plural repeated bursts based upon the guard bit offsets, the shared transmission resource including a shared radio
15 frequency; and the the eNB compensating for the phase shift to identify the MTC data corresponding to each of the plural the MTC UE.

Example 36 may include the method of example 35 and/or any other example described herein, further comprising the eNB compensating for the phase shift to identify the MTC data corresponding to each of the plural the MTC UE successively.

20 Example 37 may include the method of example 35 and/or any other example described herein, wherein further comprising the eNB compensating for the phase shift to identify the MTC data corresponding to each of the plural the MTC UE successively with successive constructive superposition of the plural repeated bursts of MTC data from each of the plural MTC UE.

25 Example 38 may include the method of example 35 and/or any other example described herein, further comprising the eNB compensating for the phase shift to identify the MTC data corresponding to each of the plural the MTC UE successively with successive constructive superposition of the plural repeated bursts of MTC data from each of the plural MTC UE concurrent with destructive superposition of the plural repeated
30 bursts of MTC data from each of the other plural MTC UE.

Example 39 may include the method of example 35 and/or any other example described herein, further comprising the eNB receiving the plural repeated bursts of MTC data from the plural MTC UE concurrently over a common time period.

Example 40 may include an apparatus, comprising means to receive a frequency offset with respect to a radio frequency of a shared transmission resource; means to transmit a first burst of MTC data over the shared transmission resource with the frequency offset from the shared radio frequency; and means to transmit a second burst of MTC data over the shared transmission resource with the frequency offset from the shared radio frequency.

Example 41 may include the apparatus of example 40 and/or any other example described herein, in which the frequency offset is received from an eNodeB.

Example 41 may include the apparatus of example 40 and/or any other example described herein, in which the first burst is of a first length, the second burst is of a second length, and the first and second lengths are different.

The description herein of illustrated implementations, including what is described in the Abstract, is not intended to be exhaustive or to limit the present disclosure to the precise forms disclosed. While specific implementations and examples are described herein for illustrative purposes, various equivalent modifications are possible within the scope of the disclosure, as those skilled in the relevant art will recognize. These modifications may be made to the disclosure in light of the above detailed description.

Claims

What is claimed is:

1. One or more computer-readable media having instructions that, when executed,
5 cause an evolved node B (eNB) to:

assign frequency offsets to one or more of plural machine-type communication (MTC) user equipment (UE) that are to communicate with the eNB over a shared transmission resource, which includes a shared radio frequency, using code-division multiple access (CDMA);

10 receive plural repeated bursts of MTC data from a first MTC UE of the plural MTC UEs over the shared transmission resource with a first phase shift based upon the frequency offset assigned to the first MTC UE; and

compensate for the first phase shift to identify the MTC data corresponding to the first MTC UE.

15 2. The one or more computer-readable media of claim 1, wherein the instructions, when executed, further cause the eNB to:

receive plural repeated bursts of MTC data from a second MTC UE of the plural MTC UEs over the shared transmission resource with a second phase shift based upon the frequency offset assigned to the second MTC UE; and

20 compensate for the phase shift to identify the MTC data corresponding to the second MTC UE.

3. The one or more computer-readable media of claim 2, wherein the instructions, when executed, further cause the eNB to:

25 compensate for the first and second phase shifts to identify the MTC data corresponding to the respective first and second MTC UEs successively.

4. The one or more computer-readable media of claim 2, wherein the instructions, when executed, further cause the eNB to:

assign first and second orthogonal codes to the respective first and second MTC UEs;

30 receive the plural repeated bursts of MTC data from the first and second MTC UEs further with application of the orthogonal codes; and

decode the orthogonal codes further to identify the MTC data corresponding to the first and second MTC UEs.

5. The one or more computer-readable media of claim 4, wherein the orthogonal codes further include Hadamard codes.

6. The one or more computer-readable media of claim 2, wherein the instructions, when executed, further cause the eNB to:

5 receive the plural repeated bursts of MTC data from the first and second MTC UEs concurrently over a common time period.

7. The one or more computer-readable media of any of claims 1-6, wherein the instructions, when executed, further cause the eNB to:

10 receive the plural repeated bursts of MTC data from the first MTC UE with at least one of the bursts of MTC data being of a length different from lengths of the other bursts of MTC data.

8. Apparatus, comprising:

one or more storage media having instructions; and

15 one or more processors coupled with the one or more storage media to execute the instructions to cause the apparatus to:

20 receive from each of plural machine-type communication (MTC) user equipment (UEs) plural repeated bursts of MTC data over a shared transmission resource with a shared radio frequency in which, for each MTC UE, a phase shift is included between each burst of MTC data based upon a frequency offset relative to the shared radio frequency ; and

identify with respect to the phase shifts the MTC data of each of the MTC UEs.

9. The apparatus of claim 8, wherein one or more processors cause the apparatus to:

25 for each MTC UE successively, compensate for the phase shift included between each burst of MTC data from the MTC UE to identify the MTC data from the MTC UE.

10. The apparatus of claim 9, wherein one or more processors cause the apparatus to:

30 compensate for the phase shift included between each burst of MTC data from the MTC UE with constructive superposition of the bursts of MTC data from the MTC UE concurrent with destructive superposition of the bursts of MTC data from the other MTC UEs.

11. The apparatus of any of claims 8-10, wherein one or more processors cause the apparatus to:

assign orthogonal codes to the plural MTC UEs;

receive the plural repeated bursts of MTC data from each of the plural MTC UEs further with application of the orthogonal codes; and

decode the orthogonal codes further to identify the MTC data corresponding to each of the plural the MTC UE.

5 12. The apparatus of claim 11, wherein the orthogonal codes further include Hadamard codes.

13. The apparatus of any of claims 8-10, wherein one or more processors cause the apparatus to:

10 receive the plural bursts of MTC data from at least one of the MTC UEs with one of the bursts of the MTC data from the at least one MTC UE being of a length different from lengths of the other bursts of MTC data from the at least one MTC UE.

14. One or more computer-readable media having instructions that, when executed, cause an evolved node B (eNB) to:

15 assign guard bit offsets to one or more of plural machine-type communication (MTC) user equipment (UE);

receive plural repeated bursts of MTC data from each of the plural MTC UE over a shared transmission resource with phase shift between the plural repeated bursts based upon the guard bit offsets, the shared transmission resource including a shared radio frequency; and

20 compensate for the phase shift to identify the MTC data corresponding to each of the plural the MTC UE.

15. The one or more computer-readable media of claim 14, wherein the instructions, when executed, further cause the eNB to:

25 compensate for the phase shift to identify the MTC data corresponding to each of the plural the MTC UE successively.

16. The one or more computer-readable media of claim 14, wherein the instructions, when executed, further cause the eNB to:

30 compensate for the phase shift to identify the MTC data corresponding to each of the plural the MTC UE successively with successive constructive superposition of the plural repeated bursts of MTC data from each of the plural MTC UE.

17. The one or more computer-readable media of claim 14, wherein the instructions, when executed, further cause the eNB to:

compensate for the phase shift to identify the MTC data corresponding to each of the plural the MTC UE successively with successive constructive superposition of the

plural repeated bursts of MTC data from each of the plural MTC UE concurrent with destructive superposition of the plural repeated bursts of MTC data from each of the other plural MTC UE.

18. The one or more computer-readable media of claim 14, wherein the
5 instructions, when executed, further cause the eNB to:

receive the plural repeated bursts of MTC data from the plural MTC UE
concurrently over a common time period.

19. Apparatus, comprising:

one or more storage media having instructions; and

10 one or more processors coupled with the one or more storage media to execute the
instructions to cause the apparatus to:

receive a frequency offset with respect to a radio frequency of a shared
transmission resource;

transmit a first burst of MTC data over the shared transmission resource with the
15 frequency offset from the shared radio frequency; and

transmit a second burst of MTC data over the shared transmission resource with
the frequency offset from the shared radio frequency.

20. The apparatus of claim 19 in which the frequency offset is received from an
eNodeB.

20 21. The apparatus of claim 19 in which the first burst of a first length, the second
burst is of a second length, and the first and second lengths are different.

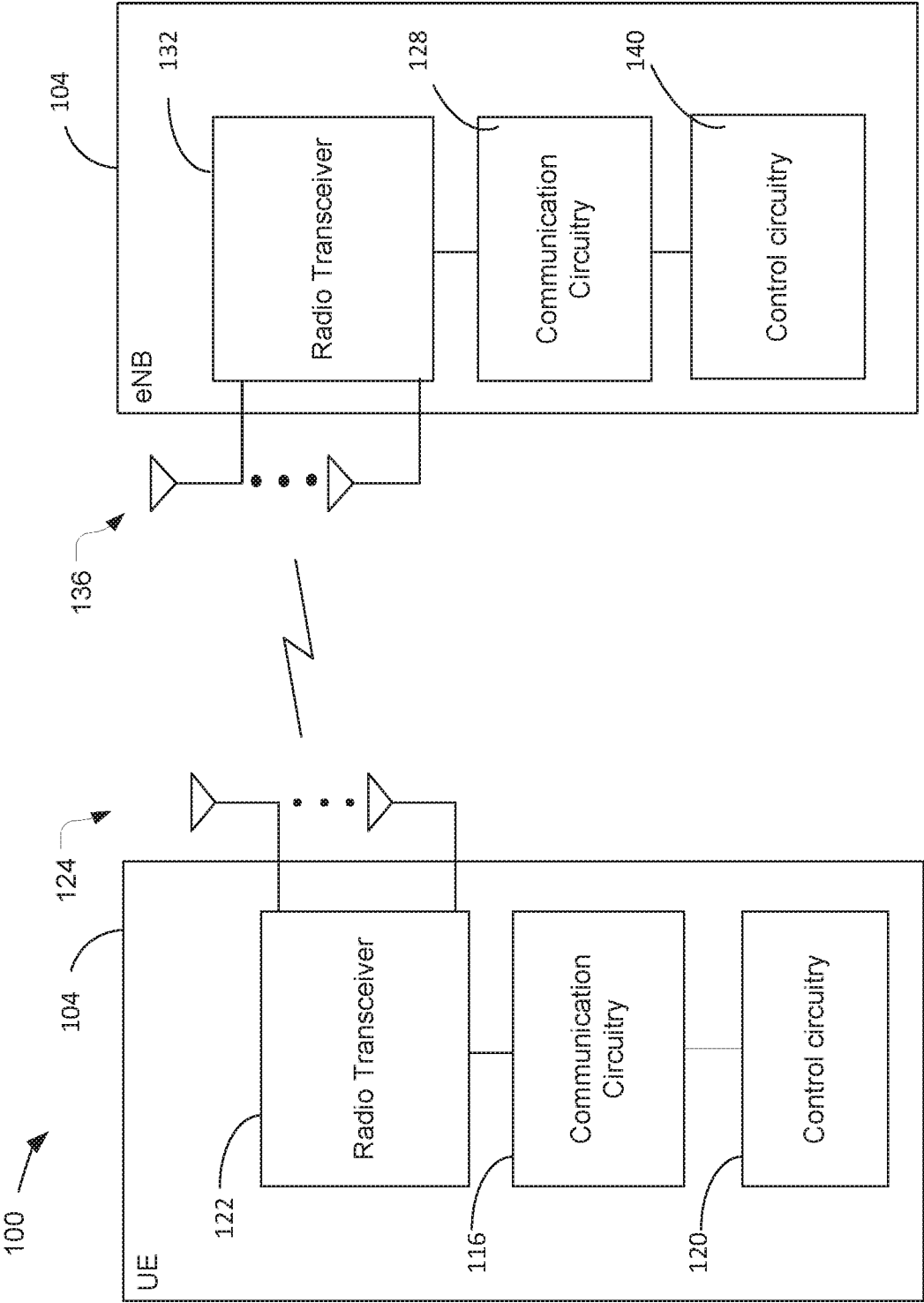
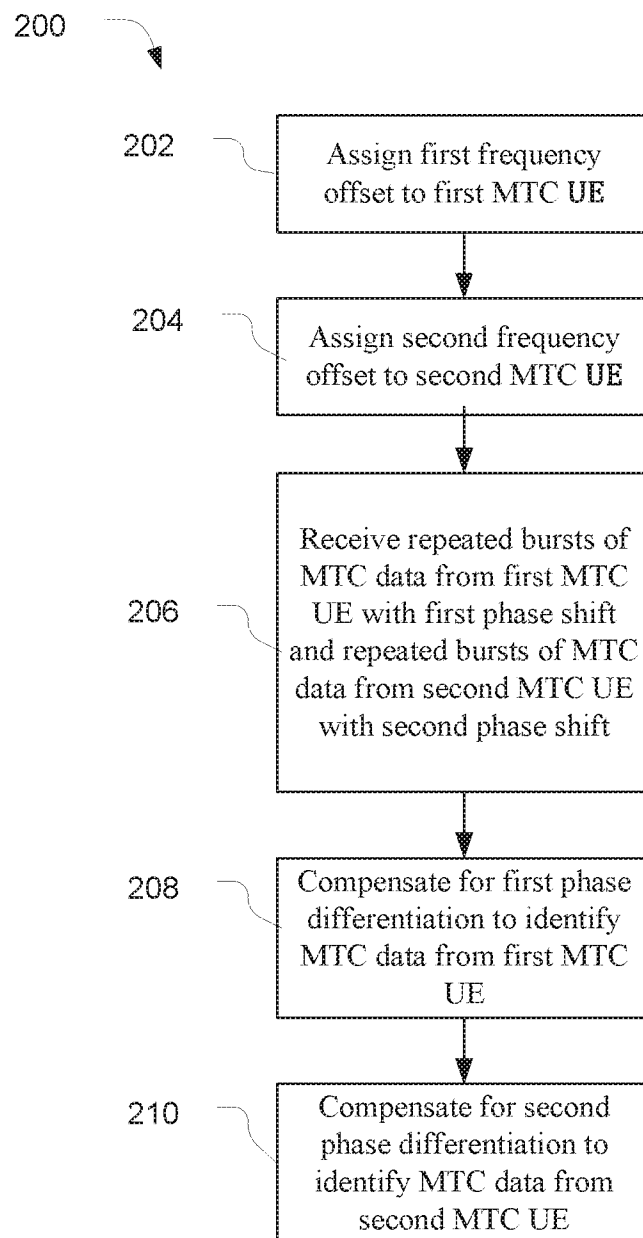
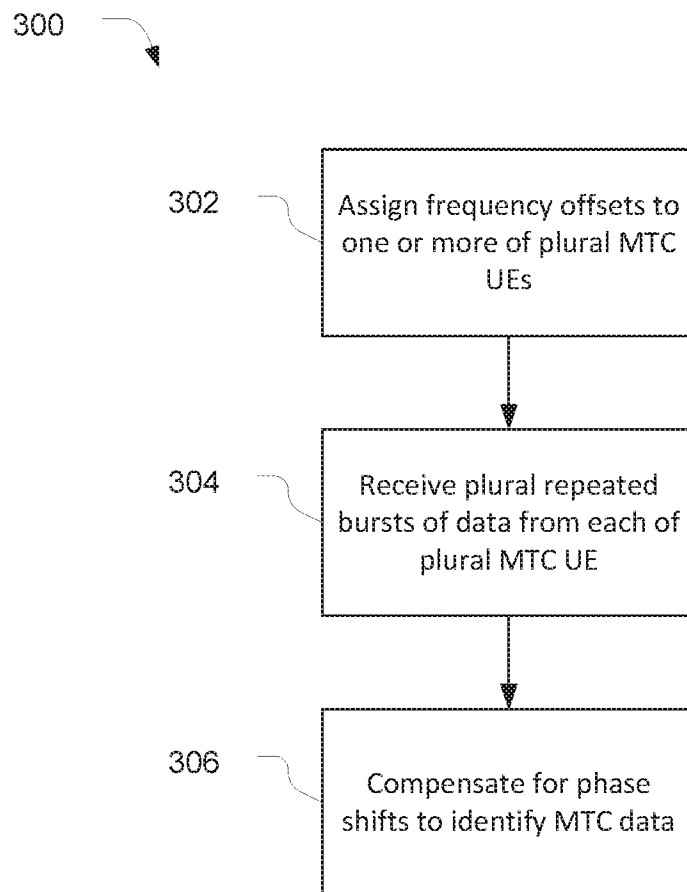


Fig. 1

2/9**Fig. 2**

3/9**Fig. 3**

400

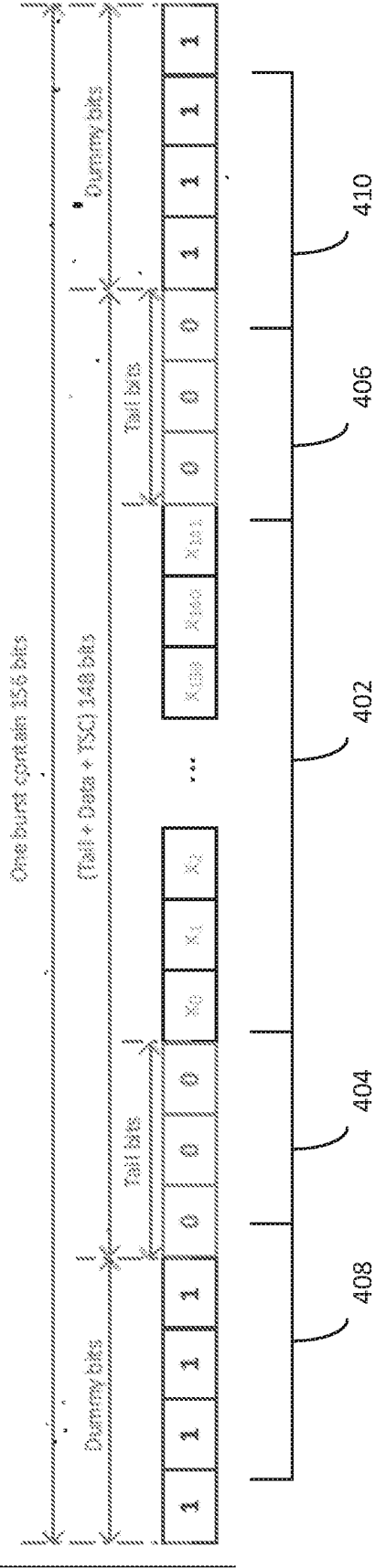
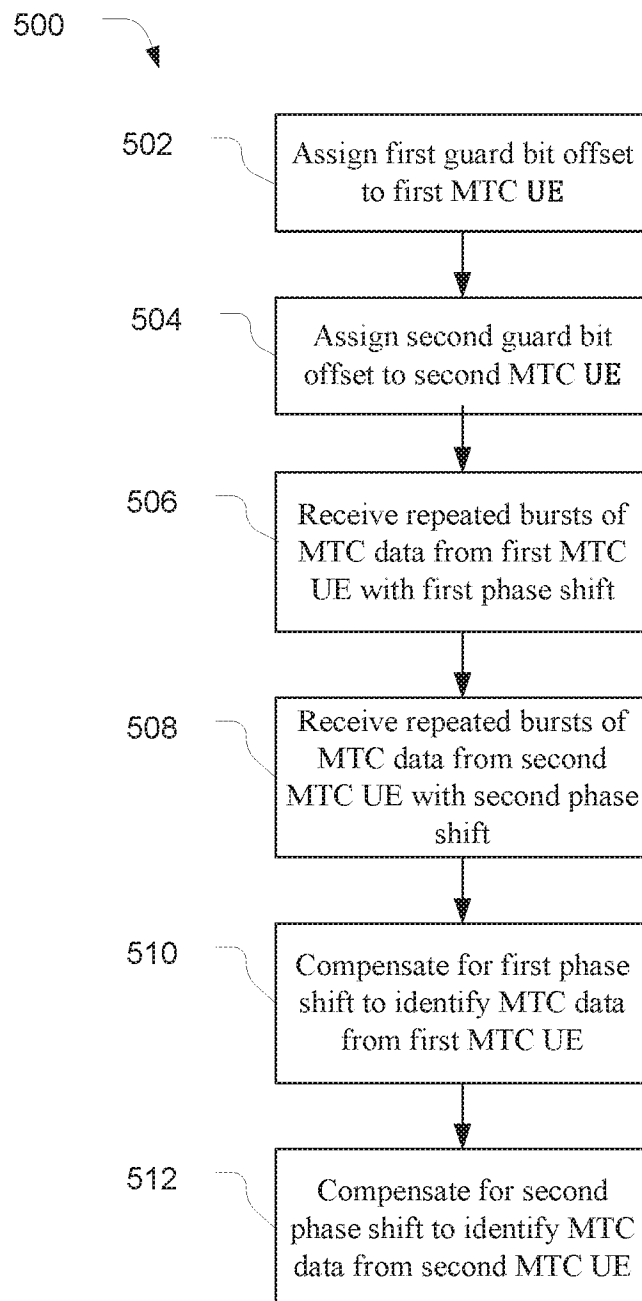
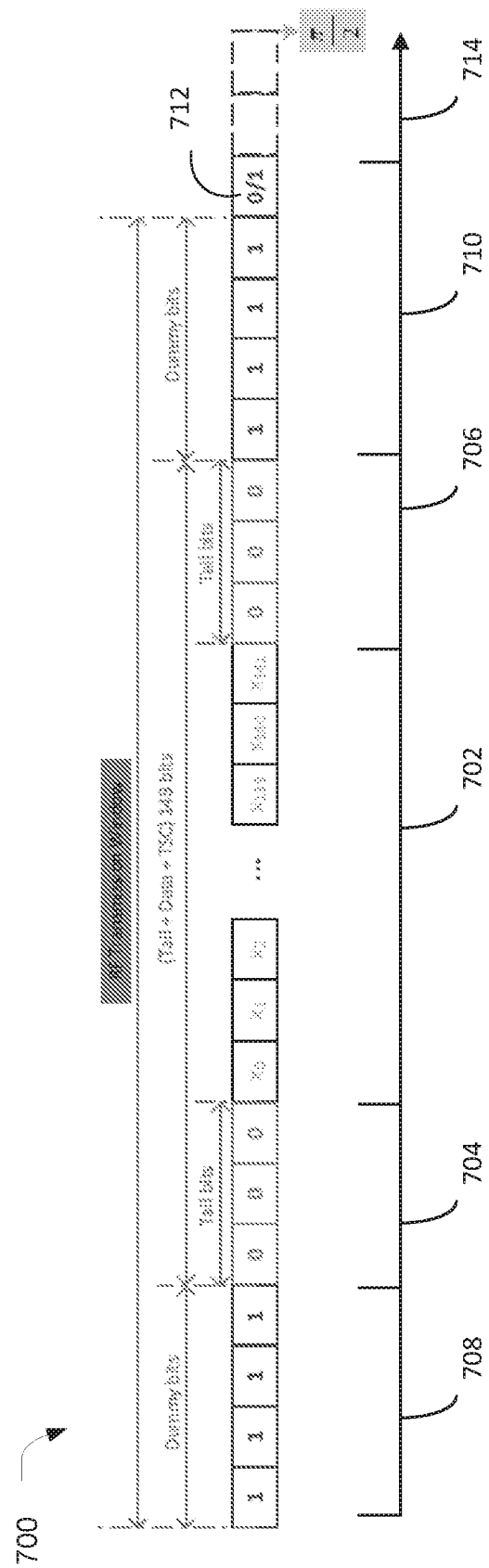
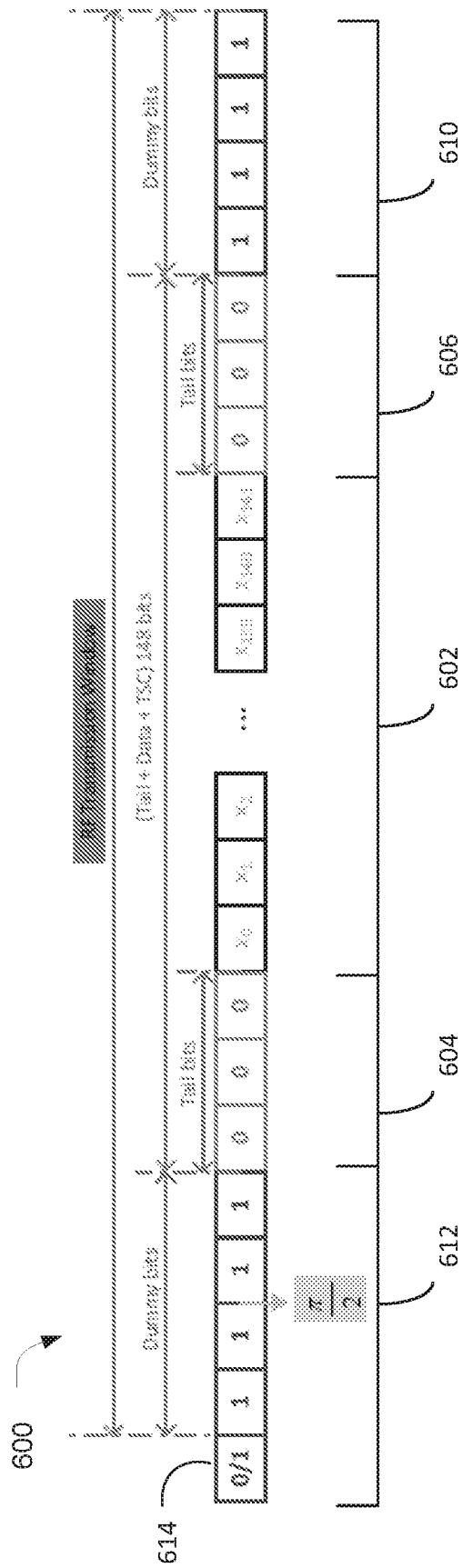


Fig. 4

5/9**Fig. 5**



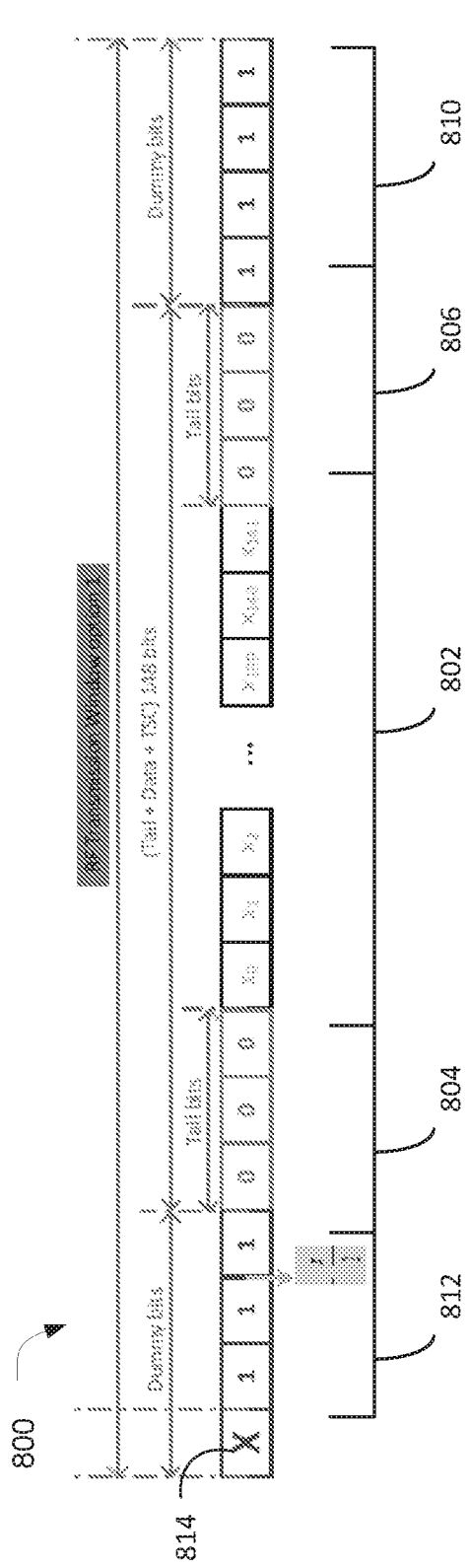


Fig. 8

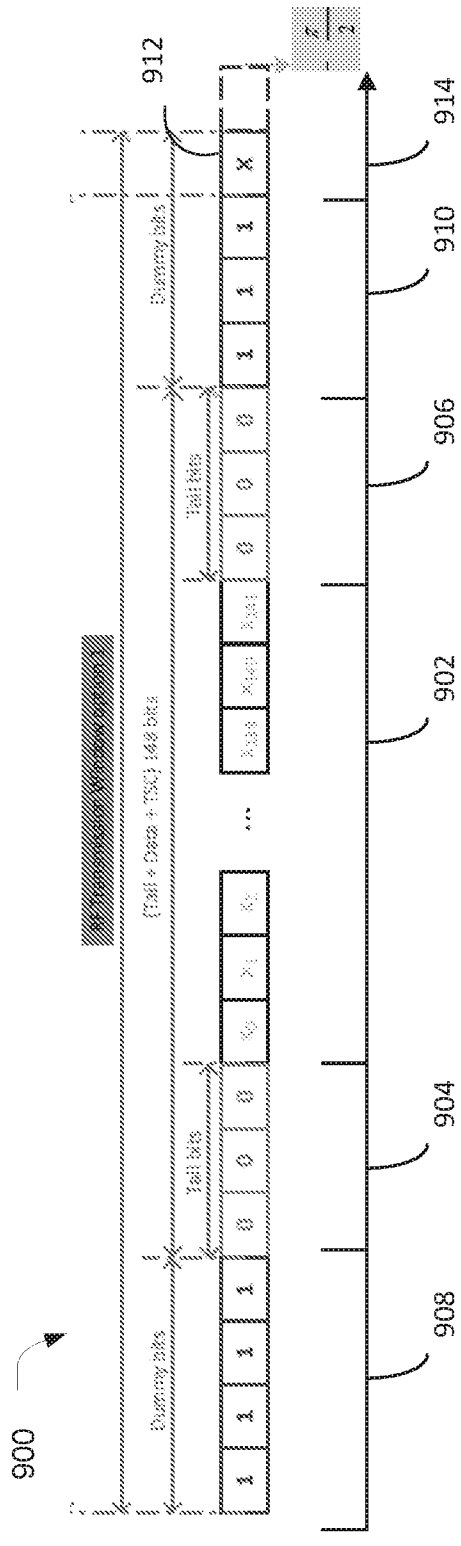


Fig. 9

8/9

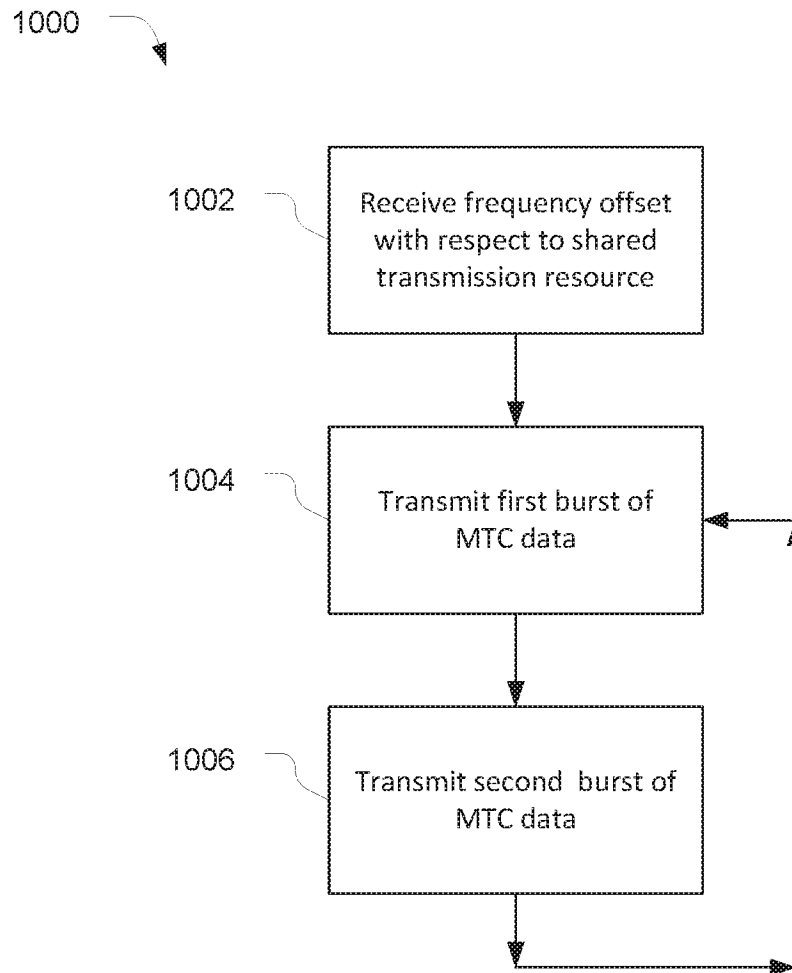


Fig. 10

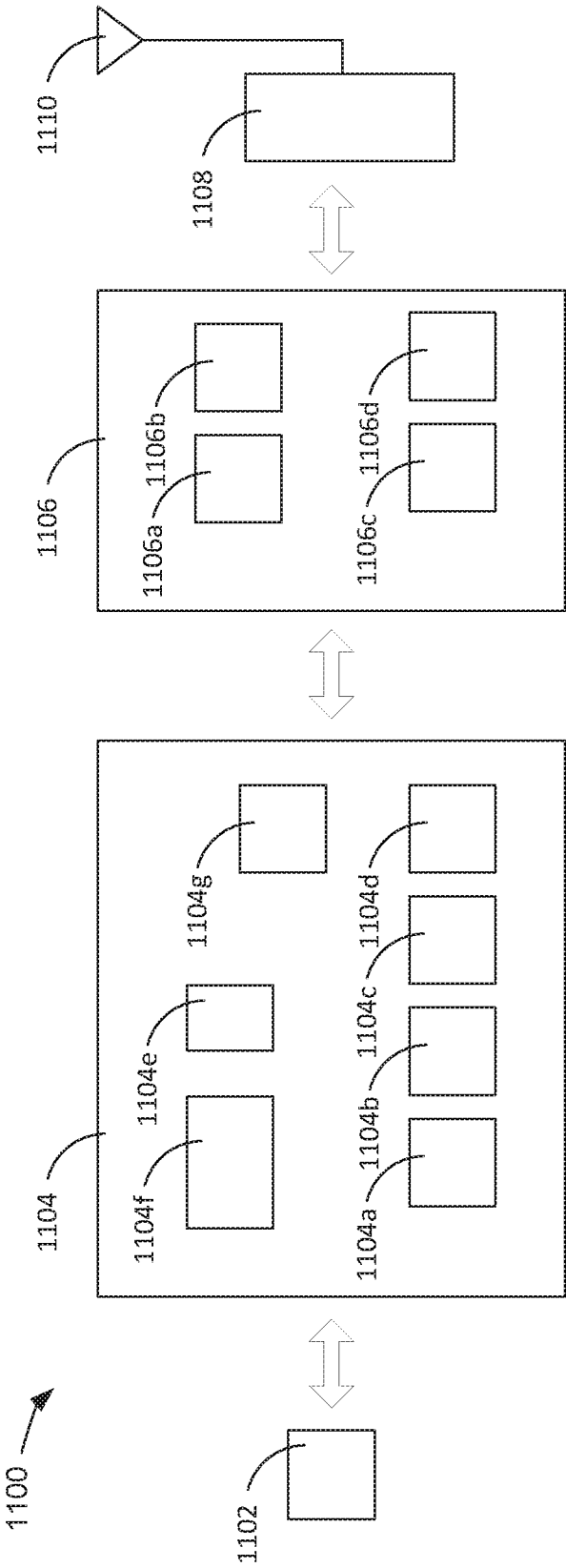


Fig. 11

INTERNATIONAL SEARCH REPORT

International application No.

PCT/CN2015/096100

A. CLASSIFICATION OF SUBJECT MATTER

H04W 28/26(2009.01)i

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; H04Q; 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)

CNPAT,CNKI,WPI,EPODOC:node B,eNB,assign,frequency offsets,machine-type communication,MTC,shar+,transmission resource,code-division multiple access,CDMA,repeated bursts,phase shift,compensat+,identify

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	CN 104769857 A (LG ELECTRONICS INC.) 08 July 2015 (2015-07-08) see description, paragraphs 12-14	1-21
A	CN 103517276 A (HUAWEI TECHNOLOGIES CO., LTD.) 15 January 2014 (2014-01-15) the whole document	1-21
A	CN 103220690 A (ZTE CORPORATION) 24 July 2013 (2013-07-24) the whole document	1-21
A	US 2013121317 A1 (ELECTRONICS AND TELECOMMUNICATIONS RESEARCH INSTITUTE) 16 May 2013 (2013-05-16) the whole document	1-21



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents:

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“P” document published prior to the international filing date but later than the priority date claimed

“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

“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

“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

“&” document member of the same patent family

Date of the actual completion of the international search

17 May 2016

Date of mailing of the international search report

12 August 2016

Name and mailing address of the ISA/CN

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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.

PCT/CN2015/096100

Patent document cited in search report			Publication date (day/month/year)	Patent family member(s)			Publication date (day/month/year)
CN	104769857	A	08 July 2015	US	2015282208	A1	01 October 2015
				WO	2014069946	A1	08 May 2014
CN	103517276	A	15 January 2014	WO	2014000514	A1	03 January 2014
CN	103220690	A	24 July 2013	WO	2013107364	A1	25 July 2013
US	2013121317	A1	16 May 2013	KR	20130054172	A	24 May 2013