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(54) Title: SYSTEMS AND METHODS OF PROVIDING A GUARD INTERVAL FOR TRANSMISSIONS IN A COMMUNICATION SYSTEM

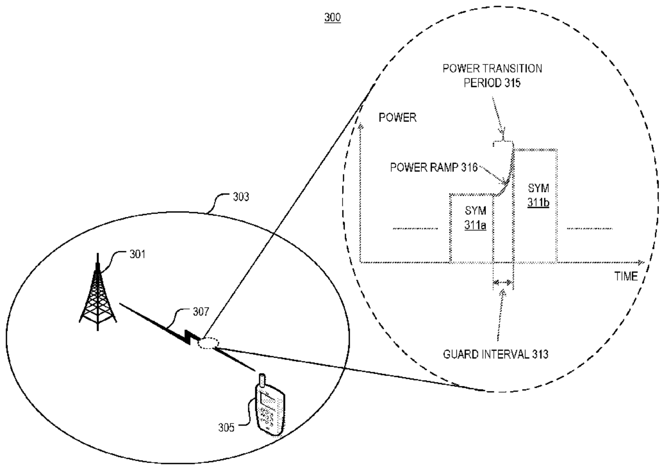

FIG. 3

(57) Abstract: A wireless device, a network node and methods performed by the wireless device and the network node for providing a guard interval for transmissions in a communication system are presented. The network node (301, 401) receives a signal (307, 407) transmitted by the wireless device (305, 405) and obtains a series of symbols (311a,b, 411a-g) from the received signal. In one exemplary embodiment, a method by the wireless device in a wireless communication system includes generating (705) the signal comprising the series of symbols, including a pair of consecutive symbols (311a,b, 411e,f, 411f,g) that are to be transmitted at different power levels, with power ramping (316, 416, 418) to occur over a power transition period (315, 415, 417) between the consecutive symbols. Further, the method includes transmitting (707) the transmit signal with a guard interval (313, 413a,b) overlapping at least partly with the power transition period.

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SYSTEMS AND METHODS OF PROVIDING A GUARD INTERVAL FOR TRANSMISSIONS IN A COMMUNICATION SYSTEM

FIELD OF DISCLOSURE

The present disclosure relates generally to the field of communications, and in particular to a wireless device, a network node and methods performed by the wireless device and the network node for providing a guard interval for transmissions in a communication system.

BACKGROUND

In Long Term Evolution (LTE), Sounding Reference Signals (SRS) are transmitted by user equipment (UE) to sound the channel in the uplink (UL) and to provide the evolved Node B (eNB) with Channel State Information (CSI). To enable CSI acquisition outside the currently scheduled bandwidth, SRS transmission bandwidth is not related to currently scheduled UL bandwidth. CSI obtained from SRS transmissions can be used at the eNB to schedule UL transmissions. Also, in reciprocal eNB implementations, SRS transmissions can be used to determine downlink (DL) precoder weights.

FIG. 1 shows an LTE subframe with a physical uplink shared channel (PUSCH) transmission and an SRS transmitted in the last symbol. In **FIG. 1**, the PUSCH and SRS bandwidths are different. Further, the PUSCH and SRS transmissions typically have different bandwidths. The PUSCH and SRS transmissions may share a common control loop or may have separate power control loops. These characteristics typically result in different power levels for SRS and PUSCH transmissions.

A Power Amplifier (PA) cannot instantaneously change its output power level but requires a ramp up or down time to adjust its power levels. As shown in **FIG. 2**, the power ramp occurs outside the SRS symbol during the PUSCH transmission. In LTE, the transient period is twenty microseconds (20 µsec.) and the SRS symbol duration is around seventy microseconds (70 µsec.), so performing the power ramp within the SRS symbol duration would impact more than half of the SRS symbol duration, resulting in severely degrading SRS performance.

PUSCH transmission would also be degraded by performing the power ramp within the PUSCH data symbol duration. This can be mitigated by the eNB adjusting the weighting of the soft values within the transient duration. This is further mitigated by the PUSCH data being time-domain interleaved (i.e., PUSCH bits are spread out in time). Even though PUSCH reception is impacted during the transient period due to time-domain interleaving, the signal can still be recovered. However, in some radio access technologies such as those considered for 5G standardization, data channels have little or no time-domain interleaving to enable early decoding. Since reduced latency is important in these 5G radio access technologies, little or no time-domain interleaving will be used, resulting in decreased data reception robustness during power ramps.

Accordingly, there is a need for improved techniques for providing a guard interval for transmissions in a communication system. In addition, other desirable features and characteristics of the present disclosure will become apparent from the subsequent detailed description and embodiments, taken in conjunction with the accompanying figures and the foregoing technical field and background.

The Background section of this document is provided to place embodiments of the present disclosure in technological and operational context, to assist those of skill in the art in understanding their scope and utility. Unless explicitly identified as such, no statement herein is admitted to be prior art merely by its inclusion in the Background section.

SUMMARY

The following presents a simplified summary of the disclosure in order to provide a basic understanding to those of skill in the art. This summary is not an extensive overview of the disclosure and is not intended to identify key/critical elements of embodiments of the disclosure or to delineate the scope of the disclosure. The sole purpose of this summary is to present some concepts disclosed herein in a simplified form as a prelude to the more detailed description that is presented later.

Briefly described, embodiments of the present disclosure relate to providing a guard interval for transmissions in a communication system. According to one aspect, a method performed by a wireless device in a wireless communication system is provided. The method includes generating a transmit signal comprising a series of symbols, including a pair of consecutive symbols that are to be transmitted at different power levels, with power ramping to occur over a power transition period between the consecutive symbols. Further, the method includes transmitting the transmit signal with a guard interval overlapping at least partly with the power transition period.

According to another aspect, the method may include transmitting the series of symbols within a subframe that comprises one or more symbol periods. Each symbol period in the subframe may have the same duration. Further, a duration of the subframe may be greater than a collective duration of the symbol periods in the subframe. Also, a duration of the guard interval may be at least a portion of a difference between the duration of the subframe and the collective duration of the symbol periods in the subframe.

According to another aspect, the method may include transmitting the series of symbols within a subframe that comprises two or more symbol periods, with at least two symbol periods having different durations. Further, a duration of the guard interval may equal one of the different symbol period durations.

According to another aspect, the method may include transmitting the series of symbols within a subframe that comprises two or more symbol periods, with at least two symbol periods having different durations. Further, a duration of the guard interval may be a function of the different symbol period durations.

According to another aspect, the method may include transmitting the series of symbols within a subframe that comprises two or more symbol periods. Each symbol period in the subframe may have the same duration. Further, a duration of the guard interval may equal an integer multiple of the symbol period duration. Also, this integer multiple may be an integer with a value greater than or equal to one.

According to another aspect, the symbols may be orthogonal frequency division multiplexed (OFDM) symbols. Each OFDM symbol may include a first or a second cyclic prefix (CP). Further, a duration of the second CP may be equivalent to a duration of the first CP and an extended duration. Also, a duration of the guard interval plus the extended duration of the second CP may equal a predetermined duration.

According to another aspect, the symbols may be OFDM symbols. Each OFDM symbol may include a first or a second predetermined signal. A duration of the second predetermined signal may be equivalent to a duration of the first predetermined signal and an extended duration. Also, a duration of the guard interval plus the extended duration of the second predetermined signal may equal a predetermined duration.

According to another aspect, the predetermined duration may be at least one of (1) a difference between a duration of the subframe and a collective duration of the symbol periods in the subframe, (2) one of different symbol period durations in the subframe, (3) a duration defined as a function of different symbol period durations in the subframe, and (4) an integer multiple of a symbol period duration.

According to another aspect, the method may include receiving, by the wireless device, from a network node in the wireless communication system, an indication of whether to use the first or the second predetermined signal.

According to another aspect, the method may include receiving, by the wireless device, from a network node in the wireless communication system, an indication of whether the transmit signal is to be transmitted with the guard interval. Further, the method may include determining whether to transmit the transmit signal with the guard interval responsive to the indication.

According to one aspect, a wireless device is provided. The wireless device is configured to generate a transmit signal comprising a series of symbols, including a pair of consecutive symbols that are to be transmitted at different power levels, with power ramping to occur over a power transition period between the consecutive symbols. Further, the wireless device is configured to transmit the transmit signal with a guard interval overlapping at least partly with the power transition period.

According to another aspect, the wireless device may be configured to transmit the series of symbols within a subframe that comprises one or more symbol periods. Each symbol period in the subframe may have the same duration. Further, a duration of the subframe may be greater than a collective duration of the symbol periods in the subframe. Also, a duration of the guard interval may be at least a portion of a difference between the duration of the subframe and the collective duration of the symbol periods in the subframe.

According to another aspect, the wireless device may be configured to transmit the series of symbols within a subframe that comprises two or more symbol periods, with at least two symbol periods having different durations. Further, a duration of the guard interval may equal one of the different symbol period durations.

According to another aspect, the wireless device may be configured to transmit the series of symbols within a subframe that comprises two or more symbol periods, with at least two symbol periods having different durations. Further, a duration of the guard interval may be a function of the different symbol period durations.

According to another aspect, the wireless device may be configured to transmit the series of symbols within a subframe that comprises two or more symbol periods. Each symbol period in the subframe may have the same duration. Further, a duration of the guard interval may equal an integer multiple of the symbol period duration. Also, the integer multiple may be an integer with a value greater than or equal to one.

According to another aspect, the wireless device may be configured to receive, from a network node in the wireless communication system, an indication of whether to use the first or the second predetermined signal.

According to another aspect, the wireless device may be configured to receive, from a network node in the wireless communication system, an indication of whether the transmit signal is to be transmitted with the guard interval. Further, the wireless device may be configured to determine whether to transmit the transmit signal with the guard interval responsive to the indication.

According to one aspect, a method performed by a network node in a wireless communication system is provided. The method includes receiving a signal having a series of symbols and with a guard interval overlapping at least partly with a power transition period.

Further, the method includes obtaining the series of symbols from the received signal, including a pair of consecutive symbols transmitted at different power levels, with power ramping occurring over the power transition period between the consecutive symbols.

According to another aspect, the method may include receiving the series of symbols within a subframe that comprises one or more symbol periods. Each symbol period in the subframe may have the same duration. Further, a duration of the subframe may be greater than a collective duration of the symbol periods in the subframe. Also, a duration of the guard interval may be at least a portion of a difference between the duration of the subframe and the collective duration of the symbol periods in the subframe.

According to another aspect, the method may include receiving the series of symbols within a subframe that comprises two or more symbol periods, with at least two symbol periods having different durations. Further, a duration of the guard interval may equal one of the different symbol period durations.

According to another aspect, the method may include receiving the series of symbols within a subframe that comprises two or more symbol periods, with at least two symbol periods having different durations. Further, a duration of the guard interval may be a function of the different symbol period durations.

According to another aspect, the method may include receiving the series of symbols within a subframe that comprises two or more symbol periods. Each symbol period in the subframe may have the same duration. Further, a duration of the guard interval may equal an integer multiple of the symbol period duration, with the integer multiple being an integer with a value greater than or equal to one.

According to another aspect, the method may include transmitting, by the network node, to a wireless device in the wireless communication system, an indication of whether to use the first or the second predetermined signal.

According to another aspect, the method may include determining whether a wireless device in the wireless communication system is to transmit the signal with the guard interval. In response to determining that the wireless device is to transmit the signal with the guard interval, the method may further include transmitting, by the network node, to the wireless device, an indication that the wireless device is to transmit the signal with the guard interval.

According to another aspect, a computer program comprising instructions which, when executed by at least one processor of a wireless device, causes the wireless device to perform any of the methods described herein.

According to one aspect, a network node is provided. The network node is configured to receive a signal having a series of symbols and with a guard interval overlapping at least partly with a power transition period. Further, the network node is configured to obtain the series of symbols from the received signal, including a pair of consecutive symbols transmitted at different power levels, with power ramping occurring over the power transition period between the consecutive symbols.

According to another aspect, the network node may be configured to receive the series of symbols within a subframe that comprises one or more symbol periods. Each symbol period in the subframe may have the same duration. Further, a duration of the subframe may be greater than a collective duration of the symbol periods in the subframe. Also, a duration of the guard interval may be at least a portion of a difference between the duration of the subframe and the collective duration of the symbol periods in the subframe.

According to another aspect, the network node may be configured to receive the series of symbols within a subframe that comprises two or more symbol periods, with at least two symbol periods having different durations. Further, a duration of the guard interval may equal one of the different symbol period durations.

According to another aspect, the network node may be configured to receive the series of symbols within a subframe that comprises two or more symbol periods, with at least two symbol periods having different durations. Further, a duration of the guard interval may be a function of the different symbol period durations.

According to another aspect, the network node may be configured to receive the series of symbols within a subframe that comprises two or more symbol periods. Each symbol period in the subframe may have the same duration. Further, a duration of the guard interval may equal an integer multiple of the symbol period duration, with the integer multiple being an integer with a value greater than or equal to one.

According to another aspect, the network node may be configured to transmit, to a wireless device in the wireless communication system, an indication of whether to use the first or second predetermined signal.

According to another aspect, the network node may be further configured to determine whether a wireless device in the wireless communication system is to transmit the signal with the guard interval. In response to determining that the wireless device is to transmit the signal with the guard interval, the network node may be further configured to transmit, to the wireless device, an indication that the wireless device is to transmit the signal with the guard interval.

According to another aspect, a computer program comprising instructions which, when executed by at least one processor of a network node, causes the network node to perform any of the methods described herein.

BRIEF DESCRIPTION OF THE DRAWINGS

The present disclosure will now be described more fully hereinafter with reference to the accompanying drawings, in which embodiments of the disclosure are shown. However, this disclosure should not be construed as limited to the embodiments set forth herein. Rather, these embodiments are provided so that this disclosure will be thorough and complete, and will fully convey the scope of the disclosure to those skilled in the art. Like numbers refer to like elements throughout.

FIG. 1 is an LTE subframe with PUSCH and SRS transmission.

FIG. 2 is a power ramp of an SRS symbol.

FIG. 3 illustrates one embodiment of a system for providing a guard interval for transmissions in a communication system in accordance with various aspects as described herein.

FIG. 4 illustrates another embodiment of a system for providing a guard interval for transmissions in a communication system in accordance with various aspects as described herein.

FIG. 5 illustrates one embodiment of a wireless device for providing a guard interval for transmissions in a communication system in accordance with various aspects as described herein.

FIG. 6 illustrates another embodiment of a wireless device for providing a guard interval for transmissions in a communication system in accordance with various aspects as described herein.

FIG. 7 illustrates one embodiment of a method by a wireless device for providing a guard interval for transmissions in a communication system in accordance with various aspects as described herein.

FIG. 8 illustrates one embodiment of a network node for providing a guard interval for transmissions in a communication system in accordance with various aspects as described herein.

FIG. 9 illustrates another embodiment of a network node for providing a guard interval for transmissions in a communication system in accordance with various aspects as described herein.

FIG. 10 illustrates one embodiment of a method by a network node for providing a guard interval for transmissions in a communication system in accordance with various aspects as described herein.

FIG. 11 illustrates another embodiment of a network node or a wireless device in accordance with various aspects as described herein.

FIG. 12 illustrates another embodiment of a method for providing a guard interval for transmissions in a communication system in accordance with various aspects as described herein.

FIG. 13 illustrates another embodiment of a method for providing a guard interval for transmissions in a communication system in accordance with various aspects as described herein

FIG. 14 illustrates another embodiment of a method for providing a guard interval for transmissions in a communication system in accordance with various aspects as described herein

FIG. 15 illustrates another embodiment of a method for providing a guard interval for transmissions in a communication system in accordance with various aspects as described herein

FIG. 16 illustrates another embodiment of a method for providing a guard interval for transmissions in a communication system in accordance with various aspects as described herein

FIG. 17 illustrates another embodiment of a method for providing a guard interval for transmissions in a communication system in accordance with various aspects as described herein

DETAILED DESCRIPTION

For simplicity and illustrative purposes, the present disclosure is described by referring mainly to exemplary embodiments thereof. In the following description, numerous specific details are set forth in order to provide a thorough understanding of the present disclosure. However, it will be readily apparent to one of ordinary skill in the art that the present disclosure may be practiced without limitation to these specific details. In this description, well known methods and structures have not been described in detail so as not to unnecessarily obscure the present disclosure.

This disclosure includes describing systems and methods for providing a guard interval for transmissions in a communication system. For example, **FIG. 3** illustrates one embodiment of a system **300** for providing a guard interval **313** for transmissions in a communication system in accordance with various aspects as described herein. In **FIG. 3**, the system **300** includes a network node **301** with coverage area **303**. The network node **301** may be configured to support one more communication systems such as LTE, Universal Mobile Telecommunications

Service (UMTS), Global System for Mobile communications (GSM), or the like. Further, the network node **301** may be a base station, an access point, or the like. The network node **301** may serve wireless device **305**. The wireless device **305** may be configured to support one or more communication systems such as LTE, UMTS, GSM, or the like. Each of the network node **301** and the wireless device **305** may send different signals to the other. In one example, the network node **301** may transmit the signal **307** to the wireless device **305**. In another example, the wireless device **305** may transmit the signal **307** to the network node **301**. The signal **307** may include a series of symbols. Further, the series of symbols may include a pair of consecutive symbols **311a-b** transmitted at different power levels (e.g., a Sounding Reference Signal, SRS, symbol at one power level and a data symbol at a different power level). A ramping up or down of the power **316** may occur over a power transition period **315** between the pair of consecutive symbols **311a-b**. In addition, a guard interval **313** may overlap at least partially the power transition period **315**.

In some embodiments, the guard interval **313** comprises a zero-valued signal transmission (e.g., a sequence of zeros) or a null transmission. In one embodiment, for instance, the signal **307** is transmitted over a wireless channel that linearly distorts the series of symbols, i.e. the series is prolonged in time. With the guard period **313**, contributions from symbol n-1 are already faded out when symbol n starts at the receiver. This simplifies reception.

In one embodiment, the base station **301** may determine whether the wireless device **305** is to transmit the signal **307** with the guard interval **313**. In response, the base station **301** may transmit an indication of whether the wireless device **305** is to transmit the signal **307** with the guard interval **313**. Correspondingly, the wireless device **305** may receive the indication from the network node **301**. In response to the indication, the wireless device **305** may determine whether or not to transmit the signal **307** with the guard interval **313**.

As shown in **FIG. 3**, the guard interval **313** in some embodiments may comprise a contiguous interval between consecutive symbols **311a** and **311b**. In this case, for example, the guard interval **313** may be one-sided in the sense that it is disposed immediately before or immediately after one of the symbols **311a** or **311b** in the pair.

In other embodiments, though, the guard interval may comprise a non-contiguous interval, e.g., with one or more symbols (at the same transmit power) intervening between different parts of the guard interval. In this case, the guard interval may be two-sided in the sense that it is disposed both immediately before and immediately after a set of one or more symbols that are to be transmitted at the same transmit power. For example, where the set of one or more symbols is flanked on both sides (i.e., before and after) by symbols transmitted at a power level different than that at which the set is transmitted, the set of one or more symbols may thereby be flanked on both sides by power transition periods. In some embodiments, the guard interval may be non-contiguously distributed into two parts, with one part before and one part after the set, so as to immediately surround the set of one or more symbols. In this way, the non-contiguous guard interval may collectively “guard” the set of one or more symbols.

FIG. 4 illustrates an embodiment where the guard interval **313** of **FIG. 3** is a non-contiguous interval. As shown, the transmit signal **407** may include a series of symbols **411a-g**. This series may include different pairs of consecutive symbols, including pairs **411e-f** and **411f-g**. A subframe **419** may include symbols **411a-f**. Further, a next subframe may include symbol **411g**. The different symbols of any given pair may be transmitted at different power levels. As shown, for instance, symbols **411e** and **411f** are transmitted at different power levels, and symbols **411f** and **411g** are transmitted at different power levels. Further, power ramping **416** may occur over the power transition period **415** between the pair of consecutive symbols **411e-f** and power ramping **418** may occur over the power transition period **417** between the pair of consecutive symbols **411f-g**. The wireless device **405** may then transmit the signal **407** with guard intervals **413a,b** overlapping at least partly with the respective power transition periods **415** and **417**. That is, the guard intervals **413a,b** represent a non-contiguous interval, part of which overlaps at least partly with the power transition period **415** and part of which overlaps at least partly with the power transition period **417**.

In **FIG. 4**, in one operation, the wireless device **405** may receive from the base station **401** an indication of whether the guard intervals **413a,b** are to be used. In response to the indication, the wireless device **405** may determine to transmit the signal **407** with the guard intervals **413a,b**. In response, the wireless device **405** may generate the signal **407** having the series of symbols **411a-g** with the pairs of consecutive symbols **411e-f** and **411f-g** with each symbol of each pair being transmitted at different power levels. Further, the power ramping may occur over the power transition period **415** between the pair of consecutive symbols **411e-f** and the power ramping may occur over the power transition period **417** between the pair of consecutive symbols **411f-g**. The wireless device **405** may then transmit the signal **407** with the guard intervals **413a,b** overlapping at least partly with the respective power transition periods **415** and **417**.

In the current embodiment, in another operation, the base station **401** may determine whether the wireless device **405** is to transmit the signal **407** with the guard interval **413**. In response, the base station **401** having coverage area **403** may transmit an indication of whether the wireless device **405** is to transmit the signal **407** with the guard interval **413**. The base station **401** may receive the signal **407** having the series of symbols **411a-g** including the pairs of consecutive samples **411e-f** and **411f-g**. A ramp up or down of the power may occur over the power transition periods **415** and **417** between the consecutive symbols **411e-f** and **411f-g**, respectively. Further, the guard interval **413** may overlap at least partly with the power transition periods **415** and **417**. In addition, the base station **401** may obtain the series of symbols **411a-g** from the signal **407**, including the pairs of consecutive symbols **411e-f** and **411f-g**, with each symbol of each pair transmitted at different power levels.

FIG. 5 illustrates one embodiment of a wireless device **500** for providing a guard interval for transmissions in a wireless communication system in accordance with various aspects as described herein. In **FIG. 5**, the wireless device **500** (e.g., UE) may include a generator circuit **501**, a transmitter or transmitter circuit **503**, a receiver or receiver circuit **505**, a determination circuit **507**, the like, or any combination thereof. The generator circuit **501** is configured to generate the transmit signal comprising a series of symbols, including a pair of consecutive symbols that are to be transmitted at different power levels, with power ramping to occur over a power transition period between the consecutive symbols. The transmitter **503** is configured to transmit the transmit signal with the guard interval overlapping at least partly with the power transition period. The receiver or receiver circuit **505** may be configured to receive, from a network node in the wireless communication system, an indication of whether the transmit signal is to be transmitted with the guard interval. Further, the determination circuit **507** may be configured to determine whether to transmit the transmit signal with the guard interval based on the indication.

FIG. 6 illustrates another embodiment of a wireless device **600** for providing a guard interval for transmissions in a wireless communication system in accordance with various aspects as described herein. In **FIG. 6**, the wireless device **600** (e.g., UE) may include processing circuit(s) **601**, radio frequency (RF) communications circuit(s) **605**, antenna(s) **607**, the like, or any combination thereof. The RF communication circuit(s) **605** may be configured to transmit or receive information to or from one or more base stations via any communication technology. This communication may occur using the one or more antennas **607** that are either internal or external to the wireless device **600**. The processing circuit(s) **601** may be configured to perform processing as described herein (e.g., the method of **FIG. 7**) such as by executing program instructions stored in memory **603**. The wireless device **600** may implement various functional means, units, or modules (e.g., via the processing circuit(s) **601**). These functional means, units, or modules (e.g., for implementing the method of **FIG. 7**) include a generating unit or module **611** for generating the transmit signal comprising a series of symbols, including a pair of consecutive symbols that are to be transmitted at different power levels, with power ramping to occur over a power transition period between the consecutive symbols. Further, these functional means, units, or modules include a transmitting unit or module **613** to transmit the transmit signal with the guard interval based on the indication. Also, these functional means, units, or modules may include a receiving unit or module **615** for receiving, from a network node in the wireless communication system, an indication of whether the transmit signal is to be transmitted with the guard interval. In addition, these functional means, units, or modules may include a determining unit or module **617** for determining whether to transmit the transmit signal with the guard interval based on the indication.

FIG. 7 illustrates one embodiment of a method **700** by a wireless device for providing a guard interval for transmissions in a wireless communication system in accordance with various aspects as described herein. In **FIG. 7**, the method **700** may start, for instance, at block **701** where it may include receiving, from a network node in the wireless communication system, an indication of whether a transmit signal is to be transmitted with a guard interval. In response to the indication, the method **700** may include determining to transmit the transmit signal with the guard interval, as referenced at block **703**. At block **705**, the method includes generating a transmit signal comprising a series of symbols, including a pair of consecutive symbols that are to be transmitted at different power levels, with power ramping to occur over a power transition period between the consecutive symbols. At block **707**, the method includes transmitting the transmit signal with the guard interval overlapping at least partly with the power transition period.

FIG. 8 illustrates one embodiment of a network node **800** for providing a guard interval for transmissions in a wireless communication system in accordance with various aspects as described herein. In **FIG. 8**, the network node **800** (e.g., base station) may include a receiver or receiver circuit **801**, an obtainer circuit **803**, a determination circuit **805**, a transmitter or transmitter circuit **807**, the like, or any combination thereof. The receiver or receiver circuit **801** is configured to receive a signal having a series of symbols and with a guard interval overlapping at least partly with a power transition period. Further, the obtainer circuit **803** is configured to obtain the series of symbols from the received signal, including a pair of consecutive symbols transmitted at different power levels, with power ramping occurring over the power transition period between the consecutive symbols. Also, the determination circuit **805** may be configured to determine whether a wireless device in the wireless communication system is to transmit the signal with the guard interval. This determination may be based on whether the power, bandwidth, or Power Spectral Density (PSD) of the consecutive symbols associated with the guard interval are the same or substantially similar (i.e., within a certain range such as 10% or 1 dB). In addition, the transmitter or transmitter circuit **807** may be configured to transmit, to the wireless device, an indication of whether the wireless device is to transmit the signal with the guard interval.

FIG. 9 illustrates another embodiment of a network node **900** for providing a guard interval for transmissions in a wireless communication system in accordance with various aspects as described herein. In **FIG. 9**, the network node **900** (e.g., base station) may include processing circuit(s) **901**, radio frequency (RF) communications circuit(s) **905**, antenna(s) **907**, the like, or any combination thereof. The RF communication circuit(s) **905** may be configured to transmit or receive information to or from one or more wireless devices via any communication technology. This communication may occur using the one or more antennas **907** that are either internal or external to the network node **900**. The processing circuit(s) **901** may be configured to perform processing as described herein (e.g., the method of **FIG. 10**) such as by executing program instructions stored in memory **903**. The network node **900** may implement various functional means, units, or modules (e.g., via the processing circuit(s) **901**). These functional means, units, or modules (e.g., for implementing the method of **FIG. 10**) include a receiving unit or module **911** for receiving a signal having a series of symbols and with a guard interval overlapping at least partly with a power transition period. Further, these functional means, units, or modules include an obtaining unit or module **913** for obtaining the series of symbols from the received signal, including a pair of consecutive symbols transmitted at different power levels, with power ramping occurring over the power transition period between the consecutive symbols. Also, these functional means, units, or modules may include a determining unit or module **915** for determining whether a wireless device in the wireless communication system is to transmit the signal with the guard interval. In addition, these functional means, units, or modules may include a transmitting unit or module **917** for transmitting, to the wireless device, an indication of whether the wireless device is to transmit the signal with the guard interval.

FIG. 10 illustrates one embodiment of a method **1000** by a network node for providing a guard interval for transmissions in a wireless communication system in accordance with various aspects as described herein. In **FIG. 10**, the method **1000** may start, for instance, at block **1001** where it may include determining whether a wireless device in the wireless communication system is to transmit the signal with the guard interval. At block **1003**, the method **1000** may include transmitting, to the wireless device, an indication of whether the wireless device is to transmit the signal with the guard interval. At block **1005**, the method **1000** includes receiving a signal having a series of symbols and with a guard interval overlapping at least partly with a power transition period. At block **1007**, the method **1000** includes obtaining the series of symbols from the received signal, including a pair of consecutive symbols transmitted at different power levels, with power ramping occurring over the power transition period between the consecutive symbols.

FIG. 11 illustrates another embodiment of a radio node **1100**, which may be a network node or a wireless device in accordance with various aspects as described herein. In some instances, the radio node **1100** may be referred as a network node, a base station (BS), an access point (AP), a wireless device, a user equipment (UE), a mobile station (MS), a terminal, a cellular phone, a cellular handset, a personal digital assistant (PDA), a smartphone, a wireless phone, an organizer, a handheld computer, a desktop computer, a laptop computer, a tablet computer, a set-top box, a television, an appliance, a game device, a medical device, a display device, a metering device, or some other like terminology. In other instances, the radio node **1100** may be a set of hardware components. In **FIG. 11**, the radio node **1100** may be configured to include a processor **1101** that is operatively coupled to an input/output interface **1105**, a radio frequency (RF) interface **1109**, a network connection interface **1111**, a memory **1115** including a random access memory (RAM) **1117**, a read only memory (ROM) **1119**, a storage medium **1131** or the like, a communication subsystem **1151**, a power source **1113**, another component, or any combination thereof. The storage medium **1131** may include an operating system **1133**, an application program **1135**, data **1137**, or the like. Specific devices may utilize all of the components shown in **FIG. 11**, or only a subset of the components, and levels of integration may vary from device to device. Further, specific devices may contain multiple instances of a component, such as multiple processors, memories, transceivers, transmitters, receivers, etc. For instance, a computing device may be configured to include a processor and a memory.

In **FIG. 11**, the processor **1101** may be configured to process computer instructions and data. The processor **1101** may be configured as any sequential state machine operative to execute machine instructions stored as machine-readable computer programs in the memory, such as one or more hardware-implemented state machines (e.g., in discrete logic, Field-Programmable Gate Array (FPGA), Application Specific Integrated Circuit (ASIC), etc.); programmable logic together with appropriate firmware; one or more stored-program, general-purpose processors, such as a microprocessor or Digital Signal Processor (DSP), together with appropriate software; or any combination of the above. For example, the processor **1101** may include two computer processors. In one definition, data is information in a form suitable for use by a computer. It is important to note that a person having ordinary skill in the art will recognize that the subject matter of this disclosure may be implemented using various operating systems or combinations of operating systems.

In the current embodiment, the input/output interface **1105** may be configured to provide a communication interface to an input device, output device, or input and output device. The radio node **1100** may be configured to use an output device via the input/output interface **1105**. A person of ordinary skill will recognize that an output device may use the same type of interface port as an input device. For example, a Universal Serial Bus (USB) port may be used to provide input to and output from the radio node **1100**. The output device may be a speaker, a sound card, a video card, a display, a monitor, a printer, an actuator, an emitter, a smartcard, another output device, or any combination thereof. The radio node **1100** may be configured to use an input device via the input/output interface **1105** to allow a user to capture information into the radio node **1100**. The input device may include a mouse, a trackball, a directional pad, a trackpad, a presence-sensitive input device, a display such as a presence-sensitive display, a scroll wheel, a digital camera, a digital video camera, a web camera, a microphone, a sensor, a smartcard, and the like. The presence-sensitive input device may include a digital camera, a digital video camera, a web camera, a microphone, a sensor, or the like to sense input from a user. The presence-sensitive input device may be combined with the display to form a presence-sensitive display. Further, the presence-sensitive input device may be coupled to the processor. The sensor may be, for instance, an accelerometer, a gyroscope, a tilt sensor, a force sensor, a magnetometer, an optical sensor, a proximity sensor, another like sensor, or any combination thereof. For example, the input device may be an accelerometer, a magnetometer, a digital camera, a microphone, and an optical sensor.

In **FIG. 11**, the RF interface **1109** may be configured to provide a communication interface to RF components such as a transmitter, a receiver, and an antenna. The network connection interface **1111** may be configured to provide a communication interface to a network **1143a**. The network **1143a** may encompass wired and wireless communication networks such as a local-area network (LAN), a wide-area network (WAN), a computer network, a wireless network, a telecommunications network, another like network or any combination thereof. For example, the network **1143a** may be a Wi-Fi network. The network connection interface **1111** may be configured to include a receiver and a transmitter interface used to communicate with one or more other nodes over a communication network according to one or more communication protocols known in the art or that may be developed, such as Ethernet, TCP/IP, SONET, ATM, or the like. The network connection interface **1111** may implement receiver and transmitter functionality appropriate to the communication network links (e.g., optical, electrical, and the like). The transmitter and receiver functions may share circuit components, software, or firmware, or alternatively may be implemented separately.

In this embodiment, the RAM **1117** may be configured to interface via the bus **1103** to the processor **1101** to provide storage or caching of data or computer instructions during the execution of software programs such as the operating system, application programs, and device drivers. In one example, the wireless device **1100** may include at least one hundred and twenty-eight megabytes (128 Mbytes) of RAM. The ROM **1119** may be configured to provide computer instructions or data to the processor **1101**. For example, the ROM **1119** may be configured to be invariant low-level system code or data for basic system functions such as basic input and output (I/O), startup, or reception of keystrokes from a keyboard that are stored in a non-volatile memory. The storage medium **1131** may be configured to include memory such as RAM, ROM, programmable read-only memory (PROM), erasable programmable read-only memory (EPROM), electrically erasable programmable read-only memory (EEPROM), magnetic disks, optical disks, floppy disks, hard disks, removable cartridges, flash drives. In one example, the storage medium **1131** may be configured to include an operating system **1133**, an application program **1135** such as a web browser application, a widget or gadget engine or another application, and a data file **1137**.

In **FIG. 11**, the processor **1101** may be configured to communicate with a network **1143b** using the communication subsystem **1151**. The network **1143a** and the network **1143b** may be the same network or networks or different network or networks. The communication subsystem **1151** may be configured to include one or more transceivers used to communicate with the network **1143b**. The one or more transceivers may be used to communicate with one or more remote transceivers of another wireless device such as a base station of a radio access network (RAN) according to one or more communication protocols known in the art or that may be developed, such as the Institute of Electrical and Electronics Engineers 802 Local Area Network (LAN) and Metropolitan Area Network (MAN) Standard (IEEE 802), Code Division Multiple Access (CDMA), Wideband CDMA (WCDMA), GSM, LTE, Universal Terrestrial Radio Access Network (UTRAN), Evolved UTRAN (E-UTRAN), Worldwide Interoperability for Microwave Access (WiMax), 5th Generation wireless systems New Radio (5G NR), Narrow-Band Internet of Things (NB-IoT), or the like.

In another example, the communication subsystem **1151** may be configured to include one or more transceivers used to communicate with one or more remote transceivers of another wireless device such as user equipment according to one or more communication protocols known in the art or that may be developed, such as IEEE 802, CDMA, WCDMA, GSM, LTE, UTRAN, E-UTRAN, WiMax, 5G NR, NB-IoT, or the like. Each transceiver may include a transmitter **1153** and/or a receiver **1155** to implement transmitter and/or receiver functionality, respectively, appropriate to the RAN links (e.g., frequency allocations and the like). Further, the transmitter **1153** and the receiver **1155** of each transceiver may share circuit components, software or firmware, or alternatively may be implemented separately.

In the current embodiment, the communication functions of the communication subsystem **1151** may include data communication, voice communication, multimedia communication, short-range communications such as Bluetooth, near-field communication, location-based communication such as the use of the global positioning system (GPS) to determine a location, another like communication function, or any combination thereof. For example, the communication subsystem **1151** may include cellular communication, Wi-Fi communication, Bluetooth communication, and GPS communication. The network **1143b** may encompass wired and wireless communication networks such as a local-area network (LAN), a wide-area network (WAN), a computer network, a wireless network, a telecommunications network, another like network or any combination thereof. For example, the network **1143b** may be a cellular network, a Wi-Fi network, and a near-field network. The power source **1113** may be configured to provide an alternating current (AC) or direct current (DC) power to components of the wireless device **1100**.

In **FIG. 11**, the storage medium **1131** may be configured to include a number of physical drive units, such as a redundant array of independent disks (RAID), a floppy disk drive, a flash memory, a USB flash drive, an external hard disk drive, thumb drive, pen drive, key drive, a high-density digital versatile disc (HD-DVD) optical disc drive, an internal hard disk drive, a Blu-

Ray optical disc drive, a holographic digital data storage (HDDS) optical disc drive, an external mini-dual in-line memory module (DIMM) synchronous dynamic random access memory (SDRAM), an external micro-DIMM SDRAM, a smartcard memory such as a subscriber identity module or a removable user identity (SIM/RUIM) module, other memory, or any combination thereof. The storage medium **1131** may allow the radio node **1100** to access computer-executable instructions, application programs or the like, stored on transitory or non-transitory memory media, to off-load data, or to upload data. An article of manufacture, such as one utilizing a communication system may be tangibly embodied in storage medium **1131**, which may comprise a computer-readable medium.

The functionality of the methods described herein may be implemented in one of the components of the radio node **1100** or partitioned across multiple components of the radio node **1100**. Further, the functionality of the methods described herein may be implemented in any combination of hardware, software, or firmware. In one example, the communication subsystem **1151** may be configured to include any of the components described herein. Further, the processor **1101** may be configured to communicate with any of such components over the bus **1103**. In another example, any of such components may be represented by program instructions stored in memory that when executed by the processor **1101** performs the corresponding functions described herein. In another example, the functionality of any of such components may be partitioned between the processor **1101** and the communication subsystem **1151**. In another example, the non-computative-intensive functions of any of such components may be implemented in software or firmware and the computative-intensive functions may be implemented in hardware.

In one embodiment, a guard interval (also referred to as a guard period) may be introduced where substantial portions of the one or more power ramps occur. By doing so allows both the SRS and data symbols to be received with little or no impairment due to the one or more power ramps.

In another embodiment, a guard interval may be introduced before the SRS symbol, after the SRS symbol, or both. Further, the power ramps may occur during the guard period. The guard period may be provided by using one or more symbol durations within the subframe as guard time before or after the SRS symbol. Hence, the guard interval may be introduced where the majority of the power ramp occurs. This may allow both the SRS and data symbols to be received with little or no impairment due to the power ramps.

In another embodiment, a guard interval may be inserted before the SRS symbol, after the SRS symbol, or both. Any power ramps that occur when the PA power changes between an SRS symbol and a corresponding data symbol may occur within the guard interval, mitigating impairments on the reception of the SRS and data symbols.

In another embodiment, a guard interval may be introduced before the SRS symbol, after the SRS symbol, or both. Each guard interval may be used to cover all or any portion of the corresponding power ramp that occurs if power changes between the SRS symbol and the corresponding data symbol. For example, **FIG. 12** illustrates another embodiment of a method **1200** for providing guard intervals **1213a,b** for transmissions in a communication system in accordance with various aspects as described herein. In **FIG. 12**, symbols **1211a-d** may be transmitted in the wireless communication system. Further, the guard intervals **1213a,b** are introduced to cover all or a portion of corresponding power ramps **1216a,b** over respective power transition periods **1215a,b** between the symbol **1211c** (e.g., SRS symbol) and the respective adjacent symbols **1211b,d** (e.g., data symbols). Further, the power ramps **1216a,b** often have exponential-decay-like behavior (i.e., transients in the power ramp slowly decay).

The time for the guard interval may be provided in various ways. In one embodiment, the frame structure may provide time for guard intervals. For example, for a subframe having duration T_{sf} and containing N symbols with duration T_{symb}, if a length of N symbols is less than a length of the subframe, then a guard interval duration may be introduced that meets the following relationship: $T_{sf} = N \cdot T_{symb} + T_{gi}$, with T_{gi} being the guard interval duration. This guard interval duration may be distributed before the SRS symbol, after the SRS symbol, or both, as one or more guard intervals. Further, parts of this guard interval duration may be used for other purposes (e.g. guard intervals for UL/DL switching in TDD systems).

In another embodiment, the subframe duration may be equivalent to an integer number of different types of symbols. For instance, the subframe duration (T_{sf}) may be provided as follows:

$$T_{sf} = N \cdot T_{symb,1} + M \cdot T_{symb,2},$$

with N and M being the number of respective first and second types of symbols and $T_{symb,1}$ and $T_{symb,2}$ being the symbol durations of the respective first and second types of symbols. While only two types of symbols are provided in this example, other types of symbols may be included. In one example, the duration of the first type of symbol ($T_{symb,1}$) may correspond to the symbol duration of a first type of OFDM symbol (e.g., subcarrier bandwidthΔF_1, CP1 if present) and the duration of the second type of symbol ($T_{symb,2}$) may correspond to the symbol duration of a second type of OFDM symbol (e.g., subcarrier bandwidth ΔF_2, CP2 if present). The subcarrier bandwidth may relate to each other via $\Delta F_2 = m/n\, \Delta F_1$with integers m and n (e.g., m or n may be one). A subframe may contain only symbols of one type (i.e., $M = 0.$) For example, **FIG. 13** illustrates another embodiment of a method **1300** for providing a guard interval **1313a,b** for transmissions in a communication system in accordance with various aspects as described herein. In **FIG. 13**, a subframe **1321** includes symbols of one type **1311a-f**. A next subframe includes symbol **1311g** of the same type. The guard intervals **1313a,b** may be introduced to cover all or a portion of corresponding power ramps **1316a,b** over respective power transition periods **1315a,b** between the symbol **1311f** (e.g., SRS symbol) and the respective adjacent symbols **1311e,g** (e.g., data symbols). The guard interval duration may then correspond to the symbol duration of one or multiple symbol durations (e.g., $T_{gi} = L \cdot T_{symb,1}$). L is the number (or fraction) of symbols (e.g., OFDM symbols) of duration $T_{symb,1}$ that are needed to generate a guard interval duration of T_{gi}. For instance, following the LTE example of 20μsec. transient period, if T_{gi} = 20μsec. and $T_{symb,1}$ = 10μsec., then L=2 symbols may be reserved for the guard interval. While the guard interval duration may be distributed before or after the symbol **1311f** (e.g., SRS symbol) as guard interval(s) **1313a,b**, the guard interval duration may also be used for other purposes (e.g., SRS symbol in the last symbol of a subframe).

If a subframe contains symbol durations with different lengths, then the guard interval may have length $T_{gi} = L_1 \cdot T_{symb,1} + L_2 \cdot T_{symb,2}$, or if only composed of symbol durations of one length it may be $T_{gi} = L_1 \cdot T_{symb,1}$ or $T_{gi} = L_2 \cdot T_{symb,2}$. In one example, if $T_{symb,1}$ = 10μsec. and $T_{symb,1}$ = 5μsec., then to achieve T_{gi} = 20μsec., either (i) L_1 = 1 and L_2 = 2, (ii) L_1 = 2, or (iii) L_2 = 4. A duration of a subframe may be $T_{sf} = (N+1)T_{symb,1}$ and the extra symbol duration $T_{symb,1}$ may be split into two symbol durations of half length (i.e., $T_{sf} = N \cdot T_{symb,1} + 2 \cdot T_{symb,2}$ with $T_{symb,2} = T_{symb,1}/2$). For example, **FIG. 14** illustrates another embodiment of a method **1400** for providing a guard interval **1413a,b** for transmissions in a communication system in accordance with various aspects as described herein. In **FIG. 14**, a subframe **1421** may include symbols **1411a-g**. A next subframe may include symbol **1411h**. The guard intervals **1413a,b** may be introduced to cover all or a portion of corresponding power ramps **1416a,b** over respective power transition periods **1415a,b** between the symbol **1411g** (e.g., SRS symbol) and the respective adjacent symbols **1411f,h** (e.g., data symbols). One of the shorter symbols **1411f** may be used for data and the duration of the second shorter symbol may be used for the guard intervals **1413a,b** having duration T_{gi}. As before, T_{gi} may be distributed before and/or after the symbol **1411g** (e.g., SRS symbol) as guard interval(s) **1413a,b** and any remaining parts (i.e., any difference between the duration of the subframe **1421** and the combined durations of the symbols **1411a-h** and the guard intervals **1413a,b**) may be used for other purposes.

In another example, **FIG. 15** illustrates another embodiment of a method **1500** for providing a guard interval **1513a,b** for transmissions in a communication system in accordance with various aspects as described herein. In **FIG. 15**, a subframe **1521** may include symbols **1511a-g**. A next subframe may include symbol **1511h**. The guard intervals **1513a,b** may be introduced to cover all or a portion of corresponding power ramps **1516a,b** over respective power transition periods **1515a,b** between the symbol **1511g** (e.g., SRS symbol) and the respective adjacent symbols **1511f,h** (e.g., data symbols). The symbols **1511a-f,h** may be $T_{symb,1}$long and the symbol **1511g** may be $T_{symb,2}$ long. The guard interval duration may be as long as before and may be used in the same manner.

The examples of **FIGs. 14-15** are restricted to the case $T_{symb,2} = T_{symb,1}/2$. This case may be extended to a more general relationship such as $T_{symb,2} = n/m\, T_{symb,1}$, or when the guard interval spans multiple symbols having the same or different durations.

In **FIGs. 14-15**, a duration of each respective subframe **1421**, **1521** corresponds to $N = 6$ symbol durations of $T_{symb,1}$and $M = 2$ symbol durations of $T_{symb,2}$. In **FIG. 14**, the symbol **1411g** (e.g., SRS symbol) is a duration of the first type of symbol ($T_{symb,1}$) with one of the data symbols **1411f** having a duration of the second type of symbol ($T_{symb,2}$) and the guard interval duration being equivalent to the duration of the second type of symbol ($T_{gi} = T_{symb,2}$) and distributed before and after the symbol **1411g** as guard intervals **1413a,b**. In **FIG. 15**, the symbol **1511g** (e.g., SRS symbol) has a duration of the second type of symbol ($T_{symb,2}$) and a guard interval duration being equivalent to a duration of the second type of symbol ($T_{gi} = T_{symb,2}$) and is distributed before and after the symbol **1511g** as guard intervals **1513a,b**.

In another embodiment, if the symbols are OFDM symbols, such symbols may have a CP. The CP may be a copy of the last portion of an OFDM symbol, which may simplify equalization in an OFDM system. The CP may be at least as long as the delay spread of the channel, with a short CP possibly impairing reception quality. The transmission of SRS symbols by UEs may be used by an eNB to estimate the channel in the UL. Further, if the eNB implementation is reciprocal, the eNB may use this channel estimate to calculate precoder weights for DL transmissions to a corresponding UE. A sufficiently long CP may be important for good channel estimation quality. If the SRS symbols are used in a Multiple Input Multiple Output (MIMO) system and pilot contamination becomes performance limiting, a longer CP may be required since SRS symbols transmitted from UEs in second-tier neighboring cells should remain orthogonal and should be received within the CP.

In another embodiment, a portion of the guard interval duration (T_{gi}) may be used to extend the CP by that portion. For example, **FIG. 16** illustrates another embodiment of a method **1600** for providing a guard interval **1613a,b** for transmissions in a communication system in accordance with various aspects as described herein. **FIG. 16** is similar to **FIG. 14** except a CP **1612a-g** is shown for each symbol **1611a-g**. In **FIG. 16**, a subframe **1621** may include symbols **1611a-f**. A next subframe may include symbol **1611g**. The guard intervals **1613a,b** may be introduced to cover all or a portion of corresponding power ramps **1616a,b** over respective power transition periods **1615a,b** between the symbol **1611f** (e.g., SRS symbol) and the respective adjacent symbols **1611e,g** (e.g., data symbols).

In another embodiment, the CP of one of the symbols (e.g., SRS symbol) may be extended by reducing the guard interval. For example, **FIG. 17** illustrates another embodiment of a method **1700** for providing a guard interval **1713a,b** for transmissions in a communication system in accordance with various aspects as described herein. In **FIG. 17**, a subframe **1721** may include symbols **1711a-f**. A next subframe may include symbol **1711g**. The guard intervals **1713a,b** may be introduced to cover all or a portion of corresponding power ramps **1716a,b** over respective power transition periods **1715a,b** between the symbol **1711f** (e.g., SRS symbol) and the respective adjacent symbols **1711e,g** (e.g., data symbols). A CP **1712a-g** is shown for each corresponding symbol **1711a-g**. Further, portions of the guard interval duration (T_{gi}) may be used to extend the CP **1712f** of the symbol **1711f** (e.g., SRS symbol), with the guard interval duration reduced accordingly. This may be useful if the guard interval duration (T_{gi}) is longer than needed to cover the power ramp durations**1715a,b**. In this case, the excess time duration may be used to extend the CP **1712f**. In conventional applications, the guard interval duration may be based on a full or half symbol duration since this may allow a guard interval that fits into a subframe or frame structure. However, this approach may result in a guard interval with a duration that is longer than required or preferred. Accordingly, as described herein, the use of a portion of the guard interval duration to extend the CP of the corresponding symbol while providing a duration of the resulting guard interval sufficient to cover the power ramp duration may result in the same or similar performance as that of the conventional applications.

In another embodiment, an OFDM system may use a unique word instead of a CP. The CP may be replaced by a known signal. Further, the length of the unique word of the corresponding symbol (e.g., SRS symbol) may be extended in the same way as shown in **FIG. 17**.

In another embodiment, an OFDM system may use a guard period (e.g., interval of zero-valued signal) instead of a CP. For instance, a zero-valued signal may be used to mitigate intersymbol interference (ISI) from one or more previous symbols. Further, the guard period may be extended in the same way as shown in **FIG. 17** (i.e., portions of T_{gi} may be used as a guard period for a corresponding symbol).

In another embodiment, an eNB may be or become aware of a guard interval when an SRS symbol is transmitted so that it may receive data and SRS symbols correctly. For instance, if there is always a guard interval when the SRS symbol is transmitted, then the eNB may receive the data and SRS symbols correctly based on the guard interval. If the guard interval is sometimes inserted when the SRS symbol is transmitted, then the eNB and UE must assume the same frame or subframe structure. The format selection of the frame or subframe structure may be signaled from the eNB to the UE (e.g., in uplink grant L1/L2 control signaling (PDCCH) or via higher layer signaling (RRC)). The format selection may also be based implicitly on other parameters such as no guard interval(s) are inserted if the power, bandwidth or PSD of the data and SRS symbols are the same or substantially similar (i.e., within a certain range such as 10% or 1 dB). Otherwise, the guard intervals are inserted.

In one embodiment, a method by a wireless device in a wireless communication system includes generating a transmit signal comprising a series of symbols, including a pair of consecutive symbols that are to be transmitted at different power levels, with power ramping to occur over a power transition period between the consecutive symbols. Further, the method includes transmitting the transmit signal with a guard interval overlapping at least partly with the power transition period.

In another embodiment, the method may further include transmitting the series of symbols within a subframe that comprises one or more symbol periods. Each symbol period in the subframe may have the same duration. Further, a duration of the subframe may be greater than a collective duration of the symbol periods in the subframe. Also, a duration of the guard interval may be at least a portion of a difference between the duration of the subframe and the collective duration of the symbol periods in the subframe.

In another embodiment, the method may further include transmitting the series of symbols within a subframe that comprises two or more symbol periods, with at least two symbol periods having different durations. Further, a duration of the guard interval may equal one of the different symbol period durations.

In another embodiment, the method may further include transmitting the series of symbols within a subframe that comprises two or more symbol periods, with at least two symbol periods having different durations. Further, a duration of the guard interval may be a function of the different symbol period durations.

In another embodiment, the method may further include transmitting the series of symbols within a subframe that comprises two or more symbol periods. Each symbol period in the subframe may have the same duration. Further, a duration of the guard interval may equal an integer multiple of the symbol period duration. Also, this integer multiple may be an integer with a value greater than or equal to one.

In another embodiment, the symbols may be OFDM symbols. Each OFDM symbol may have a first or a second CP. Further, a duration of the second CP may be equivalent to a duration of the first CP and an extended duration. Also, a duration of the guard interval plus the extended duration of the second CP may equal a predetermined duration.

In another embodiment, the symbols may be OFDM symbols. Each OFDM symbol may include a first or second predetermined signal. A duration of the second predetermined signal may be equivalent to a duration of the first predetermined signal and an extended duration.

Also, a duration of the guard interval plus the extended duration of the second predetermined signal may equal a predetermined duration.

In another embodiment, each of the first and second predetermined signals may be a zero-valued signal.

In another embodiment, the predetermined duration may be at least one of (1) a difference between a duration of the subframe and a collective duration of the symbol periods in the subframe, (2) one of different symbol period durations in the subframe, (3) a duration defined as a function of different symbol period durations in the subframe, and (4) an integer multiple of a symbol period duration.

In another embodiment, the method may further include receiving, by the wireless device, from a network node in the wireless communication system, an indication of whether to use the first or second predetermined signal.

In another embodiment, the method may further include receiving, by the wireless device, from a network node in the wireless communication system, an indication of whether the transmit signal is to be transmitted with the guard interval. Further, the method may include determining whether to transmit the transmit signal with the guard interval responsive to the indication.

In another embodiment, the method may further include determining whether to transmit the transmit signal with the guard interval based on a difference of power levels between the consecutive symbols. In one example, the method may include determining to transmit the transmit signal with the guard interval responsive to an relative difference of power levels between the consecutive symbols being at least a certain threshold (e.g., 20% or 3dB). In another example, the method may include determining to transmit the transmit signal with the guard interval responsive to either an increase of power levels between the consecutive symbols being at least a certain first threshold (e.g., 10% or 1dB) or a decrease of power levels between consecutive symbols being at least a certain second threshold (-20% or -3dB).

In another embodiment, the method may further include determining whether to transmit the transmit signal with the guard interval based on a difference of bandwidth between the consecutive symbols. In one example, the method may include determining to transmit the transmit signal with the guard interval responsive to an relative difference of bandwidth between the consecutive symbols being at least a certain threshold (e.g., 10%, or 20%, or 50 %). In another example, the method may include determining to transmit the transmit signal with the guard interval responsive to either an increase of bandwidth between the consecutive symbols being at least a certain first threshold (e.g., 10%) or a decrease of bandwidth between the consecutive symbols being at least a certain second threshold (e.g., -20%).

In another embodiment, the method may further include determining whether to transmit the transmit signal with the guard interval based on a difference of PSD between the consecutive symbols. In one example, the method may include determining to transmit the transmit signal with the guard interval responsive to an relative difference of PSD between the consecutive symbols being at least a certain threshold (e.g., 20% or 3dB). In another example, the method may include determining to transmit the transmit signal with the guard interval responsive to either an increase of PSD between the consecutive symbols being at least a certain first threshold (e.g., 10% or 1dB) or a decrease of PSD between consecutive symbols being at least a certain second threshold (e.g. -20% or -3dB).

In another embodiment, the guard interval may include a contiguous interval between the consecutive symbols.

In another embodiment, the guard interval may include a non-contiguous interval distributed before and after one of the consecutive symbols.

In another embodiment, the guard interval may include a non-contiguous interval, part of which overlaps at least partly with said power transition period and part of which overlaps at least partly with a power transition period between a different pair of symbols in the series.

In another embodiment, the non-contiguous interval may be asymmetrically distributed or symmetrically distributed.

In another embodiment, the consecutive symbols may span different frequency bandwidths.

In another embodiment, the consecutive symbols may include a data symbol that conveys data and a reference symbol that conveys a reference signal.

In another embodiment, the wireless communication system may be based on an LTE system, and the data may include PUSCH data and the reference signal may be an SRS signal.

In one embodiment, a wireless device is configured to generate a transmit signal comprising a series of symbols, including a pair of consecutive symbols that are to be transmitted at different power levels, with power ramping to occur over a power transition period between the consecutive symbols. The wireless device is further configured to transmit the transmit signal with a guard interval overlapping at least partly with the power transition period.

In another embodiment, the wireless device may be further configured to transmit the series of symbols within a subframe that comprises one or more symbol periods. Each symbol period in the subframe may have the same duration. Further, a duration of the subframe may be greater than a collective duration of the symbol periods in the subframe. Also, a duration of the guard interval may be at least a portion of a difference between the duration of the subframe and the collective duration of the symbol periods in the subframe.

In another embodiment, the wireless device may be further configured to transmit the series of symbols within a subframe that comprises two or more symbol periods, with at least two symbol periods having different durations. Further, a duration of the guard interval may equal one of the different symbol period durations.

In another embodiment, the wireless device may be further configured to transmit the series of symbols within a subframe that comprises two or more symbol periods, with at least two symbol periods having different durations. Further, a duration of the guard interval may be a function of the different symbol period durations.

In another embodiment, the wireless device may be further configured to transmit the series of symbols within a subframe that comprises two or more symbol periods. Each symbol period in the subframe may have the same duration. Further, a duration of the guard interval may equal an integer multiple of the symbol period duration. Also, this integer multiple may be an integer with a value greater than or equal to one.

In another embodiment, the wireless device may be further configured to receive, from a network node in the wireless communication system, an indication of whether to use the first or second predetermined signal.

In another embodiment, the wireless device may be further configured to receive, from a network node in the wireless communication system, an indication of whether the transmit signal is to be transmitted with the guard interval. Further, the wireless device may be further configured to determine whether to transmit the transmit signal with the guard interval responsive to the indication.

In another embodiment, the wireless device may be further configured to determine whether to transmit the transmit signal with the guard interval based on a difference of power levels between the consecutive symbols.

In another embodiment, the wireless device may be further configured to determine whether to transmit the transmit signal with the guard interval based on a difference of bandwidth between the consecutive symbols.

In another embodiment, the wireless device may be further configured to determine whether to transmit the transmit signal with the guard interval based on a difference of PSD between the consecutive symbols.

In one embodiment, a wireless device includes means for generating a transmit signal comprising a series of symbols, including a pair of consecutive symbols that are to be transmitted at different power levels, with power ramping to occur over a power transition period between the consecutive symbols. Further, the wireless device includes means for transmitting the transmit signal with a guard interval overlapping at least partly with the power transition period.

In another embodiment, the wireless device may further include means for transmitting the series of symbols within a subframe that comprises one or more symbol periods. Each symbol period in the subframe may have the same duration. Further, a duration of the subframe may be greater than a collective duration of the symbol periods in the subframe. Also, a duration of the guard interval may be at least a portion of a difference between the duration of the subframe and the collective duration of the symbol periods in the subframe.

In another embodiment, the wireless device may further include means for transmitting the series of symbols within a subframe that comprises two or more symbol periods, with at least two symbol periods having different durations. Further, a duration of the guard interval may equal one of the different symbol period durations.

In another embodiment, the wireless device may further include means for transmitting the series of symbols within a subframe that comprises two or more symbol periods, with at least two symbol periods having different durations. Further, a duration of the guard interval may be a function of the different symbol period durations.

In another embodiment, the wireless device may further include means for transmitting the series of symbols within a subframe that comprises two or more symbol periods. Each symbol period in the subframe may have the same duration. Further, a duration of the guard interval may equal an integer multiple of the symbol period duration. Also, this integer multiple may be an integer with a value greater than or equal to one.

In another embodiment, the wireless device may further include means for receiving, from a network node in the wireless communication system, an indication of whether to use the first or second predetermined signal.

In another embodiment, the wireless device may further include means for receiving, from a network node in the wireless communication system, an indication of whether the transmit signal is to be transmitted with the guard interval. Further, the wireless device may include means to determine whether to transmit the transmit signal with the guard interval responsive to the indication.

In another embodiment, the wireless device may further include means for determining whether to transmit the transmit signal with the guard interval based on a difference of power levels between the consecutive symbols.

In another embodiment, the wireless device may further include means for determining whether to transmit the transmit signal with the guard interval based on a difference of bandwidth between the consecutive symbols.

In another embodiment, the wireless device may further include means for determining whether to transmit the transmit signal with the guard interval based on a difference of PSD between the consecutive symbols.

In one embodiment, a computer program comprises instructions which, when executed by at least one processor of a wireless device, causes the wireless device to generate a transmit signal comprising a series of symbols, including a pair of consecutive symbols that are to be transmitted at different power levels, with power ramping to occur over a power transition period between the consecutive symbols. The computer program further comprises instructions which, when executed by the at least one processor of the wireless device, causes the wireless device to transmit the transmit signal with a guard interval overlapping at least partly with the power transition period.

In another embodiment, the computer program may further cause the wireless device to transmit the series of symbols within a subframe that comprises one or more symbol periods. Each symbol period in the subframe may have the same duration. Further, a duration of the subframe may be greater than a collective duration of the symbol periods in the subframe. Also, a duration of the guard interval may be at least a portion of a difference between the duration of the subframe and the collective duration of the symbol periods in the subframe.

In another embodiment, the computer program may further cause the wireless device to transmit the series of symbols within a subframe that comprises two or more symbol periods, with at least two symbol periods having different durations. Further, a duration of the guard interval may equal one of the different symbol period durations.

In another embodiment, the computer program may further cause the wireless device to transmit the series of symbols within a subframe that comprises two or more symbol periods, with at least two symbol periods having different durations. Further, a duration of the guard interval may be a function of the different symbol period durations.

In another embodiment, the computer program may further cause the wireless device to transmit the series of symbols within a subframe that comprises two or more symbol periods. Each symbol period in the subframe may have the same duration. Further, a duration of the guard interval may equal an integer multiple of the symbol period duration. Also, this integer multiple may be an integer with a value greater than or equal to one.

In another embodiment, the computer program may further cause the wireless device to receive, from a network node in the wireless communication system, an indication of whether to use the first or second predetermined signal.

In another embodiment, the computer program may further cause the wireless device to receive, from a network node in the wireless communication system, an indication of whether the transmit signal is to be transmitted with the guard interval. The computer program may further cause the wireless device to determine whether to transmit the transmit signal with the guard interval responsive to the indication.

In another embodiment, the computer program may further cause the wireless device to determine whether to transmit the transmit signal with the guard interval based on a difference of power levels between the consecutive symbols.

In another embodiment, the computer program may further cause the wireless device to determine whether to transmit the transmit signal with the guard interval based on a difference of bandwidth between the consecutive symbols.

In another embodiment, the computer program may further cause the wireless device to determine whether to transmit the transmit signal with the guard interval based on a difference of PSD between the consecutive symbols.

In another embodiment, a carrier may contain the computer program. Further, the carrier may be one of an electronic signal, optical signal, radio signal, or computer readable storage medium.

In one embodiment, a method by a network node in a wireless communication system includes receiving a signal having a series of symbols and with a guard interval overlapping at least partly with a power transition period. Further, the method includes obtaining the series of symbols from the received signal, including a pair of consecutive symbols transmitted at different power levels, with power ramping occurring over the power transition period between the consecutive symbols.

In another embodiment, the step of receiving the signal may include receiving the series of symbols within a subframe that comprises one or more symbol periods. Each symbol period in the subframe may have the same duration. Further, a duration of the subframe may be greater than a collective duration of the symbol periods in the subframe. Also, a duration of the guard interval may be at least a portion of a difference between the duration of the subframe and the collective duration of the symbol periods in the subframe.

In another embodiment, the step of receiving the signal may include receiving the series of symbols within a subframe that comprises two or more symbol periods, with at least two symbol periods having different durations. Further, a duration of the guard interval may equal one of the different symbol period durations.

In another embodiment, the step of receiving the signal may include receiving the series of symbols within a subframe that comprises two or more symbol periods, with at least two symbol periods having different durations. Further, a duration of the guard interval may be a function of the different symbol period durations.

In another embodiment, the step of receiving the signal may include receiving the series of symbols within a subframe that comprises two or more symbol periods. Each symbol period in the subframe may have the same duration. Further, a duration of the guard interval may equal an integer multiple of the symbol period duration. The integer multiple may be an integer with a value greater than or equal to one.

In another embodiment, the symbols may be OFDM symbols. Each OFDM symbol may include a first or a second CP. Further, a duration of the second CP may be equivalent to a duration of the first CP and an extended duration. Also, a duration of the guard interval plus the extended duration of the second CP may equal a predetermined duration.

In another embodiment, the symbols may be OFDM symbols. Each OFDM symbol may include a first or second predetermined signal. Further, a duration of the second predetermined signal may be equivalent to a duration of the first predetermined signal and an extended duration. Also, a duration of the guard interval plus the extended duration of the second predetermined signal may equal a predetermined duration.

In another embodiment, each of the first and second predetermined signals may be a zero-valued signal.

In another embodiment, the predetermined duration may be at least one of (1) a difference between a duration of the subframe and a collective duration of the symbol periods in the subframe, (2) one of different symbol period durations in the subframe, (3) a duration defined as a function of different symbol period durations in the subframe, and (4) an integer multiple of a symbol period duration.

In another embodiment, the method may further include transmitting, by the network node, to a wireless device in the wireless communication system, an indication of whether to use the first or second predetermined signal.

In another embodiment, the method may further include transmitting, by the network node, to the wireless device, an indication that the wireless device is to transmit the signal with the guard interval responsive to determining that the wireless device in the wireless communication system is to transmit the signal with the guard interval.

In another embodiment, the step of determining that the wireless device in the wireless communication system is to transmit the signal with the guard interval may be based on a difference of power levels between the consecutive symbols.

In another embodiment, the step of determining that the wireless device in the wireless communication system is to transmit the signal with the guard interval may be based on a difference of bandwidth between the consecutive symbols.

In another embodiment, the step of determining that the wireless device in the wireless communication system is to transmit the signal with the guard interval may be based on a difference of PSD between the consecutive symbols.

In another embodiment, the guard interval may include a contiguous interval between the consecutive symbols.

In another embodiment, the guard interval may include a non-contiguous interval distributed before and after one of the consecutive symbols.

In another embodiment, the guard interval may include a non-contiguous interval, part of which overlaps at least partly with said power transition period and part of which overlaps at least partly with a power transition period between a different pair of symbols in the series.

In another embodiment, the non-contiguous interval may be asymmetrically distributed.

In another embodiment, the non-contiguous interval may be symmetrically distributed.

In another embodiment, the consecutive symbols may span different frequency bandwidths.

In another embodiment, the consecutive symbols may include a data symbol that conveys user data and a reference symbol that conveys a reference signal.

In another embodiment, the wireless communication system may be based on an LTE system. Further, the user data may include PUSCH data and the reference signal may be an SRS signal.

In one embodiment, a network node is configured to receive a signal having a series of symbols and with a guard interval overlapping at least partly with a power transition period. The network node is further configured to obtain the series of symbols from the received signal, including a pair of consecutive symbols transmitted at different power levels, with power ramping occurring over the power transition period between the consecutive symbols.

In another embodiment, the network node may be further configured to receive the series of symbols within a subframe that comprises one or more symbol periods. Each symbol period in the subframe may have the same duration. Further, a duration of the subframe may be greater than a collective duration of the symbol periods in the subframe. Also, a duration of the guard interval may be at least a portion of a difference between the duration of the subframe and the collective duration of the symbol periods in the subframe.

In another embodiment, the network node may be further configured to receive the series of symbols within a subframe that includes two or more symbol periods, with at least two symbol periods having different durations. Further, a duration of the guard interval may equal one of the different symbol period durations.

In another embodiment, the network node may be further configured to receive the series of symbols within a subframe that includes two or more symbol periods, with at least two symbol periods having different durations. Further, a duration of the guard interval may be a function of the different symbol period durations.

In another embodiment, the network node may be further configured to receive the series of symbols within a subframe that includes two or more symbol periods. Each symbol period in the subframe may have the same duration. Further, a duration of the guard interval may equal an integer multiple of the symbol period duration. The integer multiple may be an integer with a value greater than or equal to one.

In another embodiment, the network node may be further configured to transmit, to a wireless device in the wireless communication system, an indication of whether to use the first or second predetermined signal.

In another embodiment, the network node may be further configured to determine whether a wireless device in the wireless communication system is to transmit the signal with the guard interval.

In another embodiment, the network node may be further configured to transmit, to the wireless device, an indication that the wireless device is to transmit the signal with the guard interval responsive to determining that the wireless device in the wireless communication system is to transmit the signal with the guard interval.

In another embodiment, the network node may be further configured to determine whether a wireless device in the wireless communication system is to transmit the signal with the guard interval based on a difference of power levels between the consecutive symbols.

In another embodiment, the network node may be further configured to determine whether a wireless device in the wireless communication system is to transmit the signal with the guard interval based on a difference of bandwidth between the consecutive symbols.

In another embodiment, the network node may be further configured to determine whether a wireless device in the wireless communication system is to transmit the signal with the guard interval based on a difference of PSD between the consecutive symbols.

In one embodiment, a network node includes means for receiving a signal having a series of symbols and with a guard interval overlapping at least partly with a power transition period. Further, the network node includes means for obtaining the series of symbols from the received signal, including a pair of consecutive symbols transmitted at different power levels, with power ramping occurring over the power transition period between the consecutive symbols.

In another embodiment, the network node may further include means for receiving the series of symbols within a subframe that comprises one or more symbol periods. Each symbol period in the subframe may have the same duration. Further, a duration of the subframe may be greater than a collective duration of the symbol periods in the subframe. Also, a duration of the guard interval may be at least a portion of a difference between the duration of the subframe and the collective duration of the symbol periods in the subframe.

In another embodiment, the network node may further include means for receiving the series of symbols within a subframe that includes two or more symbol periods, with at least two symbol periods having different durations. Further, a duration of the guard interval may equal one of the different symbol period durations.

In another embodiment, the network node may further include means for receiving the series of symbols within a subframe that includes two or more symbol periods, with at least two symbol periods having different durations. Further, a duration of the guard interval may be a function of the different symbol period durations.

In another embodiment, the network node may further include means for receiving the series of symbols within a subframe that includes two or more symbol periods. Each symbol period in the subframe may have the same duration. Further, a duration of the guard interval may equal an integer multiple of the symbol period duration. The integer multiple may be an integer with a value greater than or equal to one.

In another embodiment, the network node may further include means for transmitting, to a wireless device in the wireless communication system, an indication of whether to use the first or second predetermined signal.

In another embodiment, the network node may further include means for determining whether a wireless device in the wireless communication system is to transmit the signal with the guard interval.

In another embodiment, the network node may further include means for transmitting, to the wireless device, an indication that the wireless device is to transmit the signal with the guard interval responsive to determining that the wireless device in the wireless communication system is to transmit the signal with the guard interval.

In another embodiment, the network node may further include means for determining whether a wireless device in the wireless communication system is to transmit the signal with the guard interval based on a difference of power levels between the consecutive symbols.

In another embodiment, the network node may further include means for determining whether a wireless device in the wireless communication system is to transmit the signal with the guard interval based on a difference of bandwidth between the consecutive symbols.

In another embodiment, the network node may further include means for determining whether a wireless device in the wireless communication system is to transmit the signal with the guard interval based on a difference of PSD between the consecutive symbols.

In one embodiment, a computer program includes instructions which, when executed by at least one processor of a network node, causes the network node to receive a signal having a series of symbols and with a guard interval overlapping at least partly with a power transition period. The computer program further includes instructions which, when executed by the at least one processor of the network node causes the network node to obtain the series of symbols from the received signal, including a pair of consecutive symbols transmitted at different power levels, with power ramping occurring over the power transition period between the consecutive symbols.

In another embodiment, the computer program may further cause the network node to receive the series of symbols within a subframe that comprises one or more symbol periods. Each symbol period in the subframe may have the same duration. Further, a duration of the subframe may be greater than a collective duration of the symbol periods in the subframe. Also, a duration of the guard interval may be at least a portion of a difference between the duration of the subframe and the collective duration of the symbol periods in the subframe.

In another embodiment, the computer program may further cause the network node to receive the series of symbols within a subframe that includes two or more symbol periods, with at least two symbol periods having different durations. Further, a duration of the guard interval may equal one of the different symbol period durations.

In another embodiment, the computer program may further cause the network node to receive the series of symbols within a subframe that includes two or more symbol periods, with at least two symbol periods having different durations. Further, a duration of the guard interval may be a function of the different symbol period durations.

In another embodiment, the computer program may further cause the network node to receive the series of symbols within a subframe that includes two or more symbol periods. Each symbol period in the subframe may have the same duration. Further, a duration of the guard interval may equal an integer multiple of the symbol period duration. The integer multiple may be an integer with a value greater than or equal to one.

In another embodiment, the computer program may further cause the network node to transmit, to a wireless device in the wireless communication system, an indication of whether to use the first or second predetermined signal.

In another embodiment, the computer program may further cause the network node to determine whether a wireless device in the wireless communication system is to transmit the signal with the guard interval.

In another embodiment, the computer program may further cause the network node to transmit, to the wireless device, an indication that the wireless device is to transmit the signal with the guard interval responsive to determining that a wireless device in the wireless communication system is to transmit the signal with the guard interval.

In another embodiment, the computer program may further cause the network node to determine whether a wireless device in the wireless communication system is to transmit the signal with the guard interval based on a difference of power levels between the consecutive symbols.

In another embodiment, the computer program may further cause the network node to determine whether a wireless device in the wireless communication system is to transmit the signal with the guard interval based on a difference of bandwidth between the consecutive symbols.

In another embodiment, the computer program may further cause the network node to determine whether a wireless device in the wireless communication system is to transmit the signal with the guard interval based on a difference of PSD between the consecutive symbols.

In another embodiment, a carrier containing the computer program is one of an electronic signal, optical signal, radio signal, or computer readable storage medium.

ABBREVIATIONS:

Abbreviation	Explanation
3GPP	3rd Generation Partnership Project
BS	Base Station
CP	Cyclic Prefix
CRC	Cyclic Redundancy Check
CRS	Cell Specific Reference Signal
CSI	Channel State Information
CSS	Common Search Space
DL	Downlink
eNB	Evolved Node B (i.e., base station)
E-UTRA	Evolved Universal Terrestrial Radio Access
E-UTRAN	Evolved Universal Terrestrial Radio Access Network
DFT	Discrete Fourier Transform
FDD	Frequency Division Duplex

IFFT	Inverse Fast Fourier Transform
IoT	Internet of Things
LTE	Long Term Evolution
MIMO	Multiple Input Multiple Output
MSR	Multi-Standard Radio
MTC	Machine-Type Communication
NB	Narrow-Band
NB-IoT	Narrow-Band Internet of Things
NB-LTE	Narrow-Band LTE (e.g., 180 KHz bandwidth)
NB-PBCH	NB-IoT Physical Broadcast Channel
NB-PSS	NB-IoT Primary Synchronization Sequence
NB-SSS	NB-IoT Secondary Synchronization Sequence
OFDM	Orthogonal Frequency Division Modulation
OFDMA	Orthogonal Frequency Division Modulation Access
PA	Power Amplifier
PAPR	Peak-to-Average Power Ratio
PBCH	Physical Broadcast Channel
PDCCH	Physical Data Control Channel
PRACH	Physical Random Access Channel
PRB	Physical Resource Block
PSD	Power Spectral Density
PSS	Primary Synchronization Sequence
PUSCH	Physical Uplink Shared Channel
RACH	Random Access Channel
RAT	Radio Access Technology
RF	Radio Frequency
RRC	Radio Resource Control
SoC	System-on-a-Chip
SC-FDMA	Single-Carrier, Frequency Division Multiple Access

SFBC	Space Frequency Block Coding
SIM	Subscriber Identity Module or Subscriber Identification Module
SNR	Signal to Noise Ratio
SRS	Sounding Reference Signal
SSS	Secondary Synchronization Sequence
TDD	Time Division Duplex
Tx	Transmitter
UE	User Equipment
UL	Uplink
USS	UE-specific Search Space
WB-LTE	Wideband LTE (i.e., corresponds to legacy LTE)
ZC	Zadoff-Chu algorithm

The subject matter of this disclosure is in no way restricted to OFDM systems. The exemplary embodiments described herein regarding the use of a CP directed at an OFDM system may be directed at other systems. Further, while the subject matter of this disclosure is applicable to symbol or signal transmissions such as SRS transmissions on the uplink, it is also applicable to any symbol or signal transmission performed by any node on any physical link (e.g., sidelinks such as D2D or wireless self-backhaul links). In addition, while the subject matter of this disclosure may be directed at SRS symbols or signals, it is also applicable to other types of symbols or signals transmitted adjacent to one or more symbols or signals having different power levels.

The previous detailed description is merely illustrative in nature and is not intended to limit the present disclosure, or the application and uses of the present disclosure. Furthermore, there is no intention to be bound by any expressed or implied theory presented in the preceding field of use, background, summary, or detailed description. The present disclosure provides various examples, embodiments and the like, which may be described herein in terms of functional or logical block elements. The various aspects described herein are presented as methods, devices (or apparatus), systems, or articles of manufacture that may include a number of components, elements, members, modules, nodes, peripherals, or the like. Further, these methods, devices, systems, or articles of manufacture may include or not include additional components, elements, members, modules, nodes, peripherals, or the like.

Furthermore, the various aspects described herein may be implemented using standard programming or engineering techniques to produce software, firmware, hardware (e.g., circuits), or any combination thereof to control a computing device to implement the disclosed subject matter. It will be appreciated that some embodiments may be comprised of one or more generic or specialized processors such as microprocessors, digital signal processors, customized processors and field programmable gate arrays (FPGAs) and unique stored program instructions (including both software and firmware) that control the one or more processors to implement, in conjunction with certain non-processor circuits, some, most, or all of the functions of the methods, devices and systems described herein. Alternatively, some or all functions could be implemented by a state machine that has no stored program instructions, or in one or more application specific integrated circuits (ASICs), in which each function or some combinations of certain of the functions are implemented as custom logic circuits. Of course, a combination of the two approaches may be used. Further, it is expected that one of ordinary skill, notwithstanding possibly significant effort and many design choices motivated by, for example, available time, current technology, and economic considerations, when guided by the concepts and principles disclosed herein will be readily capable of generating such software instructions and programs and ICs with minimal experimentation.

The term “article of manufacture” as used herein is intended to encompass a computer program accessible from any computing device, carrier, or media. For example, a computer-readable medium may include: a magnetic storage device such as a hard disk, a floppy disk or a magnetic strip; an optical disk such as a compact disk (CD) or digital versatile disk (DVD); a smart card; and a flash memory device such as a card, stick or key drive. Additionally, it should be appreciated that a carrier wave may be employed to carry computer-readable electronic data including those used in transmitting and receiving electronic data such as electronic mail (e-mail) or in accessing a computer network such as the Internet or a local area network (LAN). Of course, a person of ordinary skill in the art will recognize many modifications that may be made to this configuration without departing from the scope of the subject matter of this disclosure.

Throughout the specification and the embodiments, the following terms take at least the meanings explicitly associated herein, unless the context clearly dictates otherwise. Relational terms such as “first” and “second," and the like may be used solely to distinguish one entity or action from another entity or action without necessarily requiring or implying any actual such relationship or order between such entities or actions. The term “or” is intended to mean an inclusive “or” unless specified otherwise or clear from the context to be directed to an exclusive form. Further, the terms “a,” “an,” and “the” are intended to mean one or more unless specified otherwise or clear from the context to be directed to a singular form. The term “include” and its various forms are intended to mean including but not limited to. References to “one embodiment,” “an embodiment,” “example embodiment,” “various embodiments,” and other like terms indicate that the embodiments of the disclosed technology so described may include a particular function, feature, structure, or characteristic, but not every embodiment necessarily includes the particular function, feature, structure, or characteristic. Further, repeated use of the phrase “in one embodiment” does not necessarily refer to the same embodiment, although it may. The terms “substantially,” “essentially,” “approximately,” “about” or any other version thereof, are defined as being close to as understood by one of ordinary skill in the art, and in one non-limiting embodiment the term is defined to be within 10%, in another embodiment within 5%, in another embodiment within 1% and in another embodiment within 0.5%. A device or structure that is “configured” in a certain way is configured in at least that way, but may also be configured in ways that are not listed.

CLAIMS

What is claimed:

1. A method performed by a wireless device in a wireless communication system, the method comprising:

generating (705) a transmit signal (307, 407) comprising a series of symbols (311a,b, 411a-g), including a pair of consecutive symbols (311a,b, 411e,f, 411f,g) that are to be transmitted at different power levels, with power ramping (316, 416, 418) to occur over a power transition period (315, 415, 417) between the consecutive symbols; and

transmitting (707) the transmit signal with a guard interval (313, 413a,b) overlapping at least partly with the power transition period.

2. The method of claim 1, wherein said transmitting comprises transmitting the series of symbols within a subframe that comprises one or more symbol periods, wherein each symbol period in the subframe has the same duration, wherein a duration of the subframe is greater than a collective duration of the symbol periods in the subframe, and a duration of the guard interval is at least a portion of a difference between the duration of the subframe and the collective duration of the symbol periods in the subframe.

3. The method of claim 1, wherein said transmitting comprises transmitting the series of symbols within a subframe that comprises two or more symbol periods, with at least two symbol periods having different durations, wherein a duration of the guard interval equals one of the different symbol period durations.

4. The method of claim 1, wherein said transmitting comprises transmitting the series of symbols within a subframe that comprises two or more symbol periods, with at least two symbol periods having different durations, wherein a duration of the guard interval is a function of the different symbol period durations.

5. The method claim 1, wherein said transmitting comprises transmitting the series of symbols within a subframe that comprises two or more symbol periods, wherein each symbol period in the subframe has the same duration, wherein a duration of the guard interval equals an integer multiple of the symbol period duration, wherein the integer multiple is an integer with a value greater than or equal to one.

6. The method of any of claims 1-5, wherein the symbols are orthogonal frequency division multiplexed (OFDM) symbols, each OFDM symbol includes a first or a second cyclic prefix (CP), a duration of the second CP is equivalent to a duration of the first CP and an extended duration, and wherein a duration of the guard interval plus the extended duration of the second CP equals a predetermined duration.

7. The method of any of claims 1-5, wherein the symbols are orthogonal frequency division multiplexed (OFDM) symbols, each OFDM symbol includes a first or a second predetermined signal, a duration of the second predetermined signal is equivalent to a duration of the first predetermined signal and an extended duration, and wherein a duration of the guard interval plus the extended duration of the second predetermined signal equals a predetermined duration.

8. The method of any of claims 6-7, wherein the predetermined duration is at least one of:
a difference between a duration of the subframe and a collective duration of the symbol periods in the subframe;
one of different symbol period durations in the subframe;
a duration defined as a function of different symbol period durations in the subframe; and
an integer multiple of a symbol period duration.

9. The method of claim 7, further comprising:
receiving, by the wireless device, from a network node in the wireless communication system, an indication of whether to use the first or the second predetermined signal.

10. The method of any of claims 1-9, further comprising:
receiving (701), by the wireless device, from a network node in the wireless communication system, an indication of whether the transmit signal is to be transmitted with the guard interval; and
in response to the indication, determining (703) whether to transmit the transmit signal with the guard interval.

11. A wireless device configured to:

generate (705) a transmit signal (307, 407) comprising a series of symbols (311a,b, 411a-g), including a pair of consecutive symbols (311a,b, 411e,f, 411f,g) that are to be transmitted at different power levels, with power ramping (316, 416, 418) to occur over a power transition period (315, 415, 417) between the consecutive symbols; and

transmit (707) the transmit signal with a guard interval (313, 413a,b) overlapping at least partly with the power transition period.

12. The wireless device of claim 11, wherein the wireless device is further configured to transmit the series of symbols within a subframe that comprises one or more symbol periods, wherein each symbol period in the subframe has the same duration, wherein a duration of the subframe is greater than a collective duration of the symbol periods in the subframe, and a duration of the guard interval is at least a portion of a difference between the duration of the subframe and the collective duration of the symbol periods in the subframe.

13. The wireless device of claim 11, wherein the wireless device is further configured to transmit the series of symbols within a subframe that comprises two or more symbol periods, with at least two symbol periods having different durations, wherein a duration of the guard interval equals one of the different symbol period durations.

14. The wireless device of claim 11, wherein the wireless device is further configured to transmit the series of symbols within a subframe that comprises two or more symbol periods, with at least two symbol periods having different durations, wherein a duration of the guard interval is a function of the different symbol period durations.

15. The wireless device claim 11, wherein the wireless device is further configured to transmit the series of symbols within a subframe that comprises two or more symbol periods, wherein each symbol period in the subframe has the same duration, wherein a duration of the guard interval equals an integer multiple of the symbol period duration, wherein the integer multiple is an integer with a value greater than or equal to one.

16. The wireless device of any of claims 11-15, wherein the symbols are orthogonal frequency division multiplexed (OFDM) symbols, each OFDM symbol includes a first or a second cyclic prefix (CP), a duration of the second CP is equivalent to a duration of the first CP and an extended duration, and wherein a duration of the guard interval plus the extended duration of the second CP equals a predetermined duration.

17. The wireless device of any of claims 11-15, wherein the symbols are orthogonal frequency division multiplexed (OFDM) symbols, each OFDM symbol includes a first or a second predetermined signal, a duration of the second predetermined signal is equivalent to a duration of the first predetermined signal and an extended duration, and wherein a duration of the guard interval plus the extended duration of the second predetermined signal equals a predetermined duration.

18. The wireless device of any of claims 16-17, wherein the predetermined duration is at least one of:

a difference between a duration of the subframe and a collective duration of the symbol periods in the subframe;

one of different symbol period durations in the subframe;

a duration defined as a function of different symbol period durations in the subframe; and

an integer multiple of a symbol period duration.

19. The wireless device of claim 17, the wireless device is further configured to:

receive, from a network node in the wireless communication system, an indication of whether to use the first or the second predetermined signal.

20. The wireless device of any of claims 11-19, the wireless device is further configured to:

receive (701), from a network node in the wireless communication system, an indication of whether the transmit signal is to be transmitted with the guard interval; and

in response to the indication, determine (703) whether to transmit the transmit signal with the guard interval.

21. A computer program comprising instructions which, when executed by at least one processor of a wireless device, causes the wireless device to perform the method of any of claims 1-20.

22. A method performed by a network node in a wireless communication system, the method comprising:

receiving (1005) a signal (307, 407) having a series of symbols (311a,b, 411a-g) and with a guard interval (313, 413a,b) overlapping at least partly with a power transition period (315, 415, 417); and

obtaining (1007) the series of symbols from the received signal, including a pair of consecutive symbols (311a,b, 411e,f, 411f,g) transmitted at different power levels, with power ramping (316, 416, 418) occurring over the power transition period between the consecutive symbols.

23. The method of claim 22, wherein said receiving comprises receiving the series of symbols within a subframe that comprises one or more symbol periods, wherein each symbol period in the subframe has the same duration, wherein a duration of the subframe is greater than a collective duration of the symbol periods in the subframe, and a duration of the guard interval is at least a portion of a difference between the duration of the subframe and the collective duration of the symbol periods in the subframe.

24. The method of claim 22, wherein said receiving comprises receiving the series of symbols within a subframe that comprises two or more symbol periods, with at least two symbol periods having different durations, wherein a duration of the guard interval equals one of the different symbol period durations.

25. The method of claim 22, wherein said receiving comprises receiving the series of symbols within a subframe that comprises two or more symbol periods, with at least two symbol periods having different durations, wherein a duration of the guard interval is a function of the different symbol period durations.

26. The method claim 22, wherein said receiving comprises receiving the series of symbols within a subframe that comprises two or more symbol periods, wherein each symbol period in the subframe has the same duration, wherein a duration of the guard interval equals an integer multiple of the symbol period duration, wherein the integer multiple is an integer with a value greater than or equal to one.

27. The method of any of claims 22-26, wherein the symbols are orthogonal frequency division multiplexed (OFDM) symbols, each OFDM symbol includes a first or a second cyclic prefix (CP), a duration of the second CP is equivalent to a duration of the first CP and an extended duration, and wherein a duration of the guard interval plus the extended duration of the second CP equals a predetermined duration.

28. The method of any of claims 22-26, wherein the symbols are orthogonal frequency division multiplexed (OFDM) symbols, each OFDM symbol includes a first or a second predetermined signal, a duration of the second predetermined signal is equivalent to a duration of the first predetermined signal and an extended duration, and wherein a duration of the guard interval plus the extended duration of the second predetermined signal equals a predetermined duration.

29. The method of any of claims 27-28, wherein the predetermined duration is at least one of:

a difference between a duration of the subframe and a collective duration of the symbol periods in the subframe;

one of different symbol period durations in the subframe;

a duration defined as a function of different symbol period durations in the subframe; and

an integer multiple of a symbol period duration.

30. The method of claim 28, further comprising: transmitting, by the network node, to a wireless device in the wireless communication system, an indication of whether to use the first or the second predetermined signal.

31. The method of any of claims 22-30, further comprising:

determining (1001) whether a wireless device in the wireless communication system is to transmit the signal with the guard interval; and

in response to determining that the wireless device is to transmit the signal with the guard interval, transmitting (1003), by the network node, to the wireless device, an indication that the wireless device is to transmit the signal with the guard interval.

32. A network node configured to:

receive (1005) a signal (307, 407) having a series of symbols (311a,b, 411a-g) and with a guard interval (313, 413a,b) overlapping at least partly with a power transition period (315, 415, 417); and

obtain (1007) the series of symbols from the received signal, including a pair of consecutive symbols (311a,b, 411e,f, 411f,g) transmitted at different power levels, with power ramping (316, 416, 418) occurring over the power transition period between the consecutive symbols.

33. The network node of claim 32, wherein the network node is further configured to receive the series of symbols within a subframe that comprises one or more symbol periods, wherein each symbol period in the subframe has the same duration, wherein a duration of the subframe is greater than a collective duration of the symbol periods in the subframe, and a duration of the guard interval is at least a portion of a difference between the duration of the subframe and the collective duration of the symbol periods in the subframe.

34. The network node of claim 32, wherein the network node is further configured to receive the series of symbols within a subframe that comprises two or more symbol periods, with at least two symbol periods having different durations, wherein a duration of the guard interval equals one of the different symbol period durations.

35. The network node of claim 32, wherein the network node is further configured to receive the series of symbols within a subframe that comprises two or more symbol periods, with at least two symbol periods having different durations, wherein a duration of the guard interval is a function of the different symbol period durations.

36. The network node claim 32, wherein the network node is further configured to receive the series of symbols within a subframe that comprises two or more symbol periods, wherein each symbol period in the subframe has the same duration, wherein a duration of the guard interval equals an integer multiple of the symbol period duration, wherein the integer multiple is an integer with a value greater than or equal to one.

37. The network node of any of claims 32-36, wherein the symbols are orthogonal frequency division multiplexed (OFDM) symbols, each OFDM symbol includes a first or a second cyclic prefix (CP), a duration of the second CP is equivalent to a duration of the first CP and an extended duration, and wherein a duration of the guard interval the extended duration of the second CP equals a predetermined duration.

38. The network node of any of claims 32-36, wherein the symbols are orthogonal frequency division multiplexed (OFDM) symbols, each OFDM symbol includes a first or a second predetermined signal, a duration of the second predetermined signal is equivalent to a duration of the first predetermined signal and an extended duration, and wherein a duration of the guard interval plus the extended duration of the second predetermined signal equals a predetermined duration.

39. The network node of any of claims 37-38, wherein the predetermined duration is at least one of:

a difference between a duration of the subframe and a collective duration of the symbol periods in the subframe;

one of different symbol period durations in the subframe;

a duration defined as a function of different symbol period durations in the subframe; and

an integer multiple of a symbol period duration.

40. The network node of claim 38, wherein the network node is further configured to:
transmit, to a wireless device in the wireless communication system, an indication of whether to use the first or the second predetermined signal.

41. The network node of any of claims 32-40, wherein the network node is further configured to:
determine (1001) whether a wireless device in the wireless communication system is to transmit the signal with the guard interval; and
in response to determining that the wireless device is to transmit the signal with the guard interval, transmit (1003), to the wireless device, an indication that the wireless device is to transmit the signal with the guard interval.

42. A computer program comprising instructions which, when executed by at least one processor of a network node, causes the network node to perform the method of any of claims 22-31.

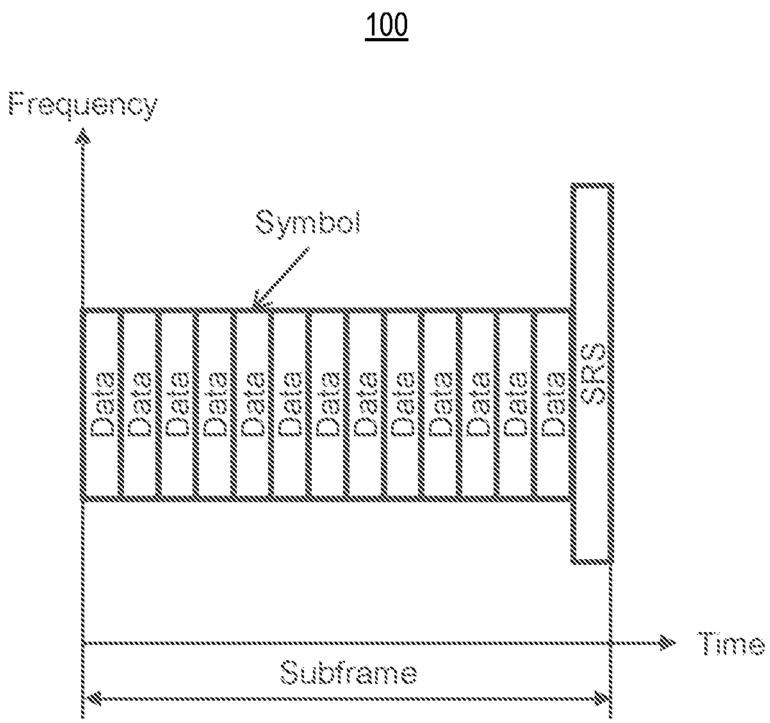

FIG. 1 (PRIOR ART)

200

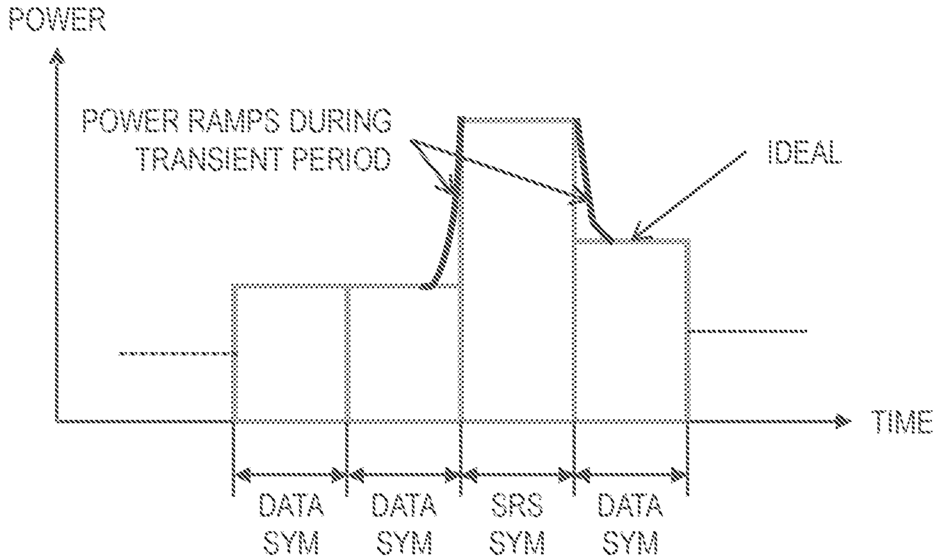

FIG. 2 (PRIOR ART)

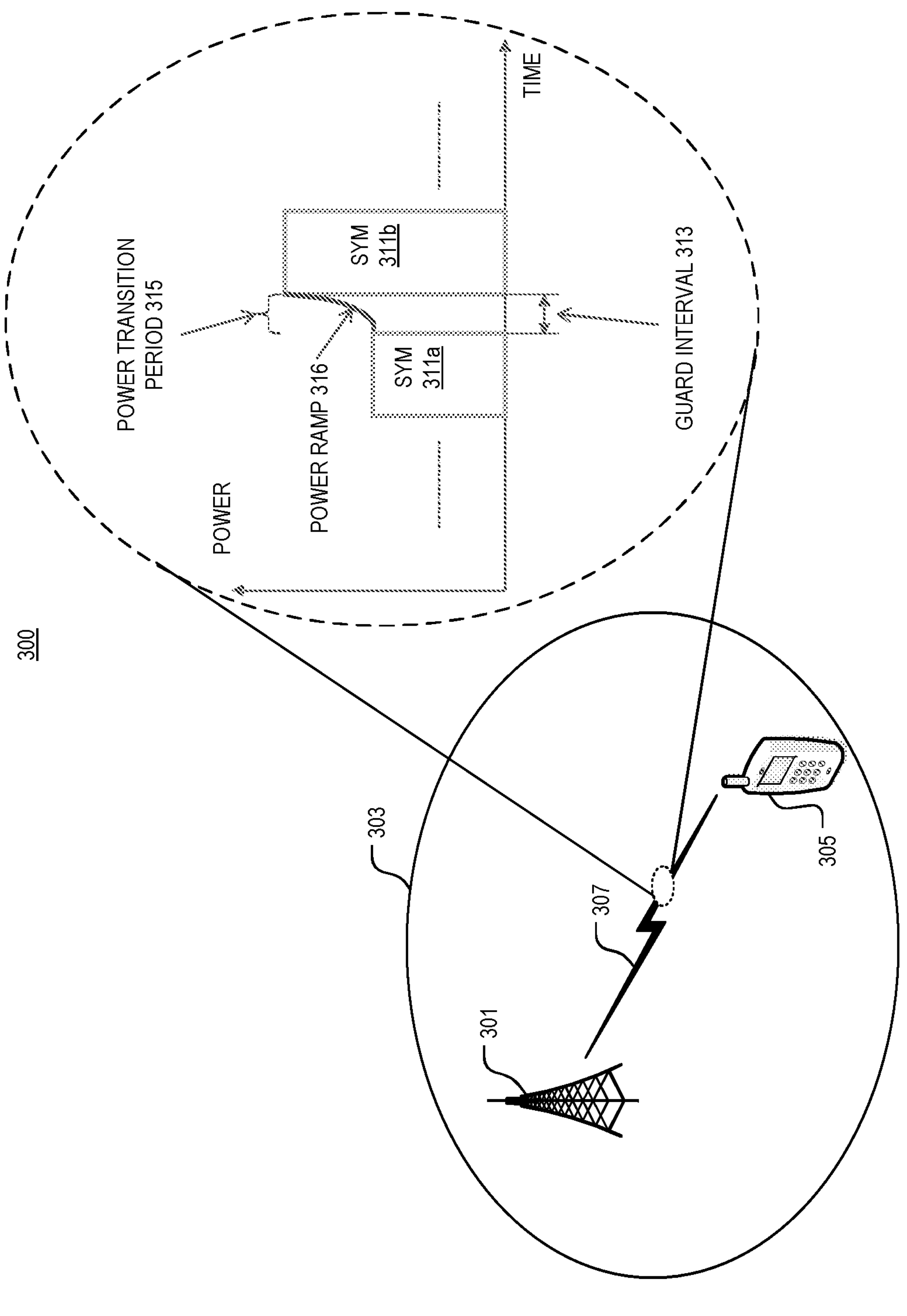
300
POWER TRANSITION
PERIOD 315
POWER RAMP 316
POWER
TIME
SYM
311b
SYM
311a
GUARD INTERVAL 313
303
307
301
305

FIG. 3

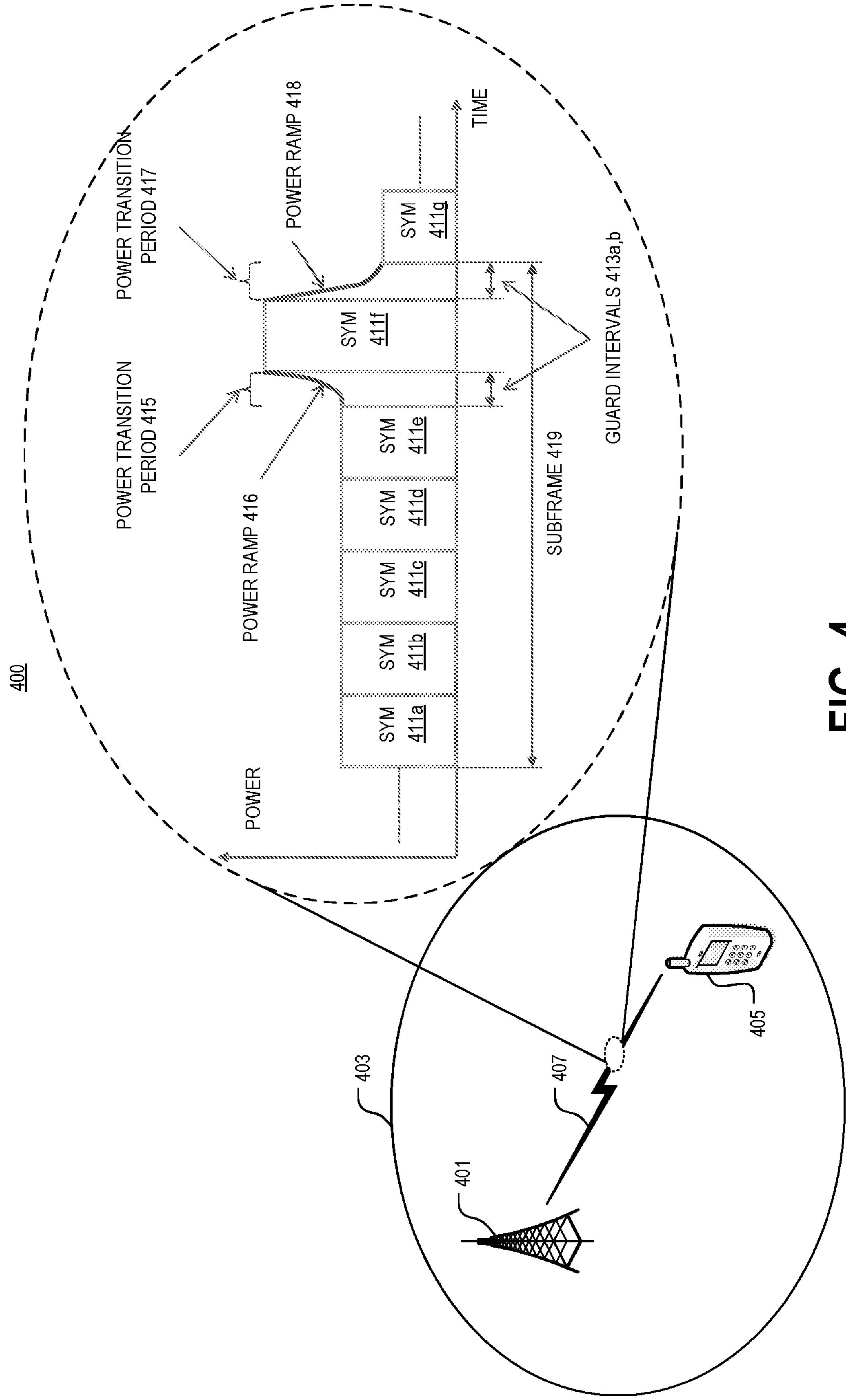
400
POWER
TIME
SYM 411a
SYM 411b
SYM 411c
SYM 411d
SYM 411e
SYM 411f
SYM 411g
POWER TRANSITION PERIOD 415
POWER TRANSITION PERIOD 417
POWER RAMP 416
POWER RAMP 418
SUBFRAME 419
GUARD INTERVALS 413a,b
401
403
405
407

FIG. 4

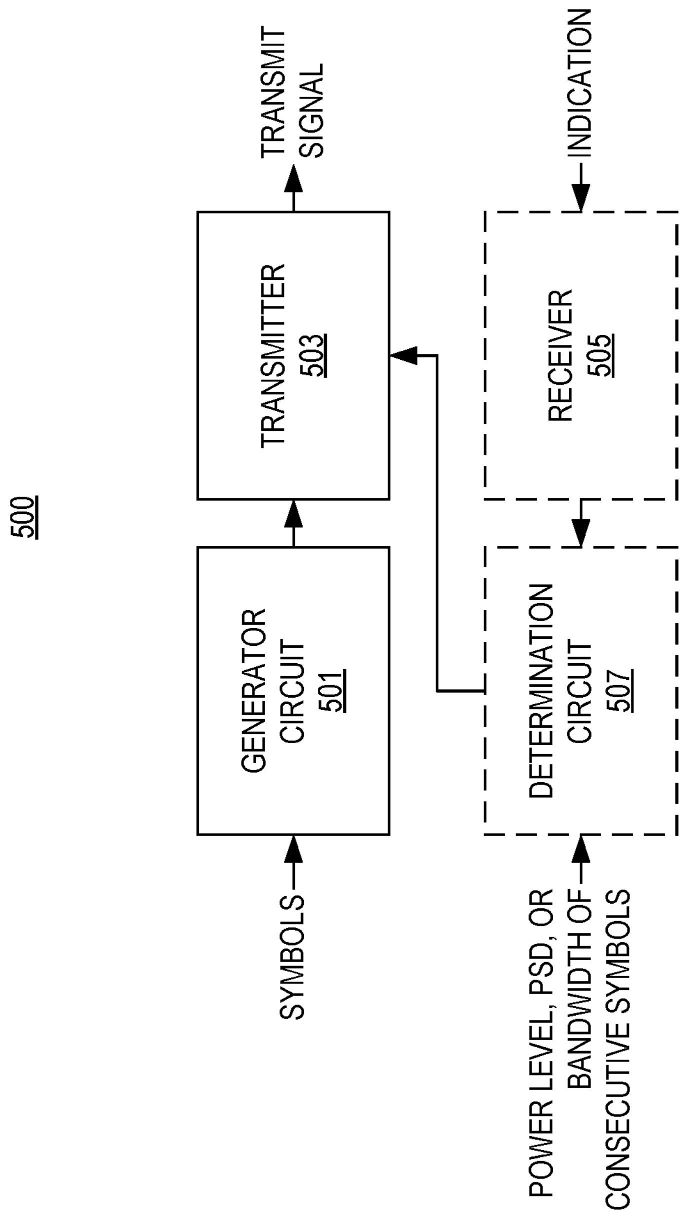
500
TRANSMIT SIGNAL
INDICATION
TRANSMITTER 503
RECEIVER 505
GENERATOR CIRCUIT 501
DETERMINATION CIRCUIT 507
SYMBOLS
POWER LEVEL, PSD, OR BANDWIDTH OF CONSECUTIVE SYMBOLS

FIG. 5

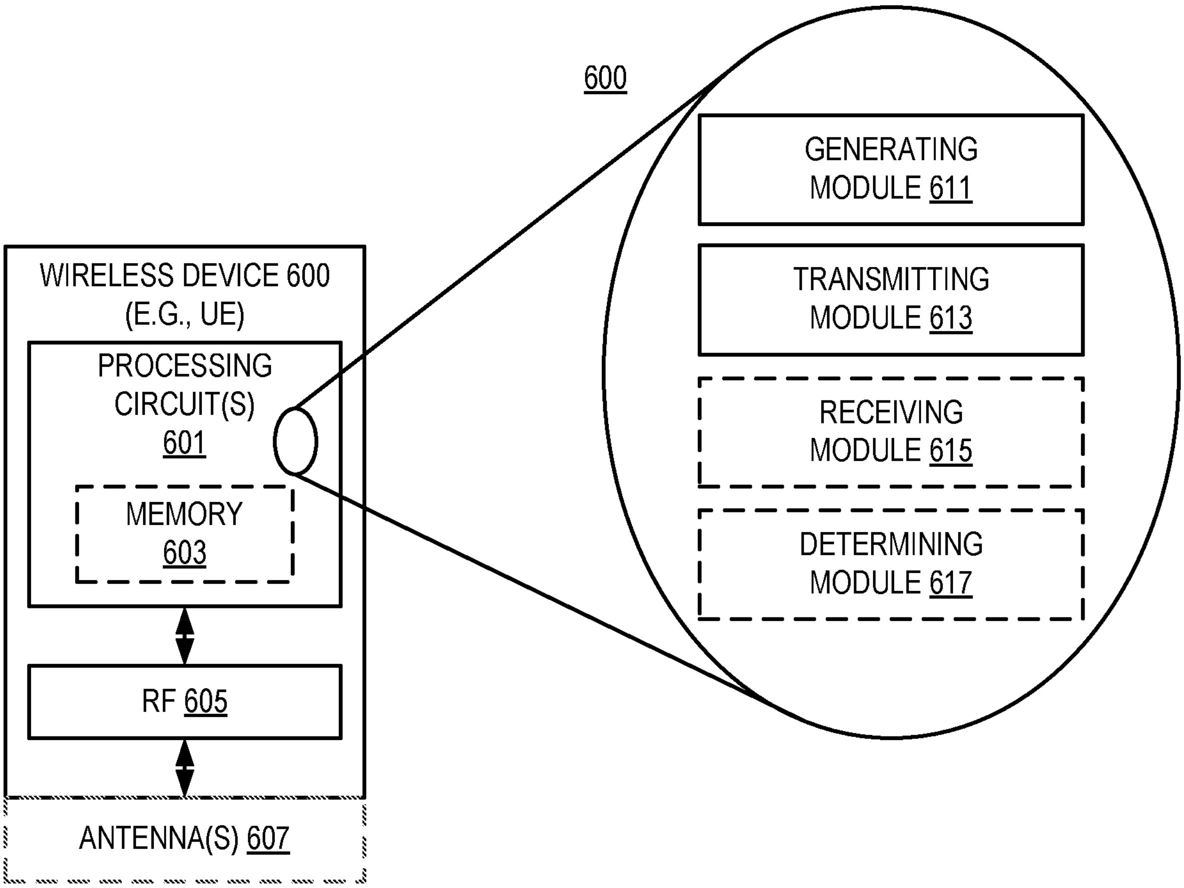
600
WIRELESS DEVICE 600
(E.G., UE)
PROCESSING
CIRCUIT(S)
601
MEMORY
603
RF 605
ANTENNA(S) 607
GENERATING
MODULE 611
TRANSMITTING
MODULE 613
RECEIVING
MODULE 615
DETERMINING
MODULE 617

FIG. 6

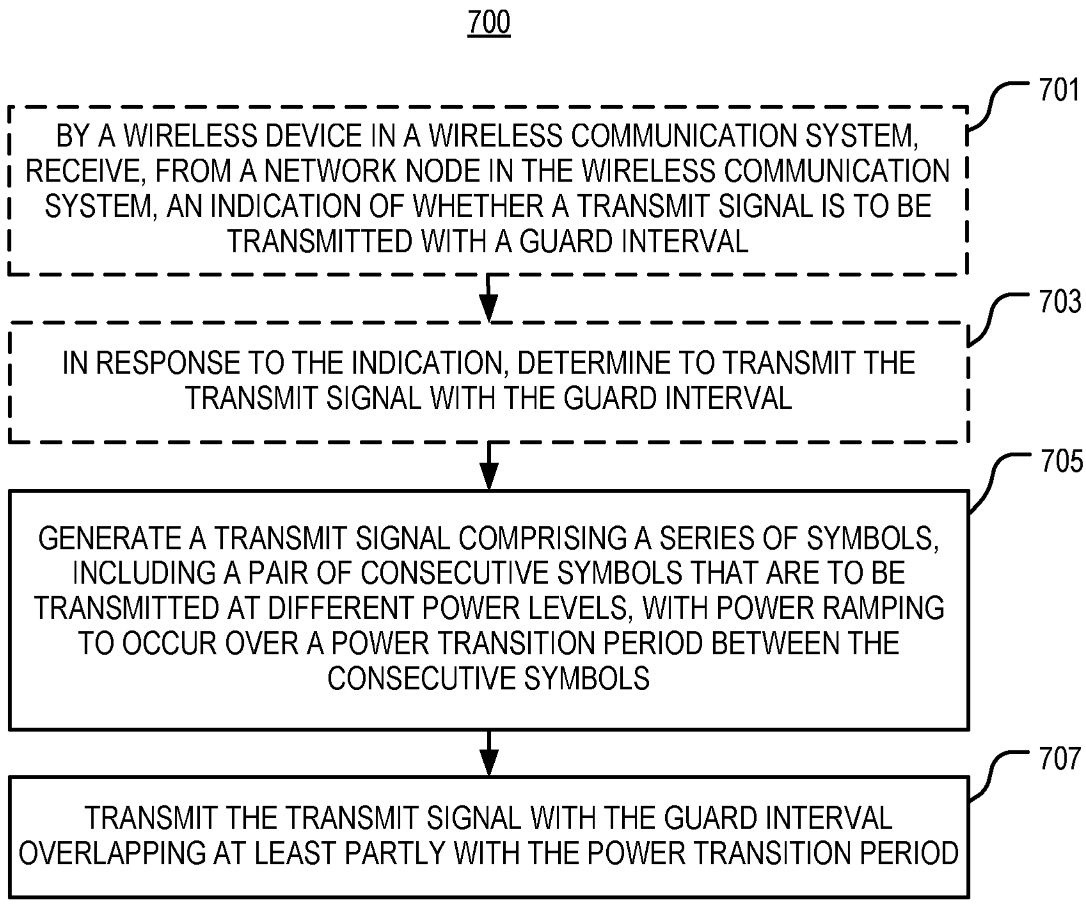
700
701
BY A WIRELESS DEVICE IN A WIRELESS COMMUNICATION SYSTEM, RECEIVE, FROM A NETWORK NODE IN THE WIRELESS COMMUNICATION SYSTEM, AN INDICATION OF WHETHER A TRANSMIT SIGNAL IS TO BE TRANSMITTED WITH A GUARD INTERVAL
703
IN RESPONSE TO THE INDICATION, DETERMINE TO TRANSMIT THE TRANSMIT SIGNAL WITH THE GUARD INTERVAL
705
GENERATE A TRANSMIT SIGNAL COMPRISING A SERIES OF SYMBOLS, INCLUDING A PAIR OF CONSECUTIVE SYMBOLS THAT ARE TO BE TRANSMITTED AT DIFFERENT POWER LEVELS, WITH POWER RAMPING TO OCCUR OVER A POWER TRANSITION PERIOD BETWEEN THE CONSECUTIVE SYMBOLS
707
TRANSMIT THE TRANSMIT SIGNAL WITH THE GUARD INTERVAL OVERLAPPING AT LEAST PARTLY WITH THE POWER TRANSITION PERIOD

FIG. 7

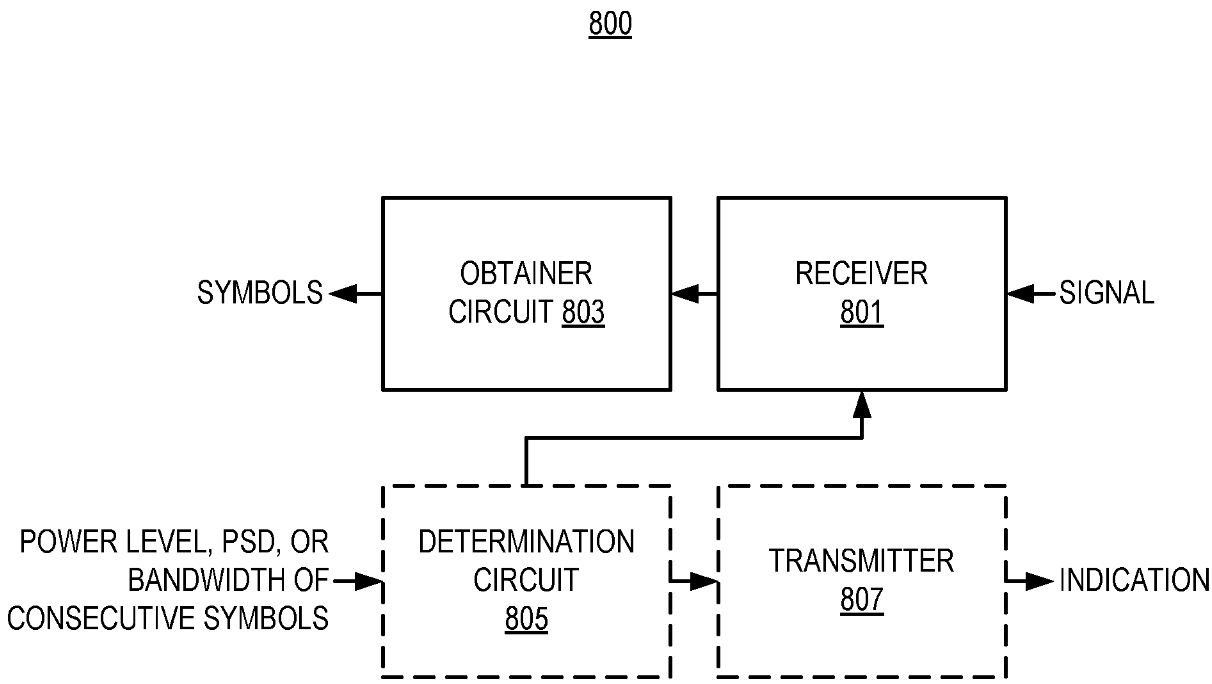
800
SYMBOLS
OBTAINER CIRCUIT 803
RECEIVER 801
SIGNAL
POWER LEVEL, PSD, OR BANDWIDTH OF CONSECUTIVE SYMBOLS
DETERMINATION CIRCUIT 805
TRANSMITTER 807
INDICATION

FIG. 8

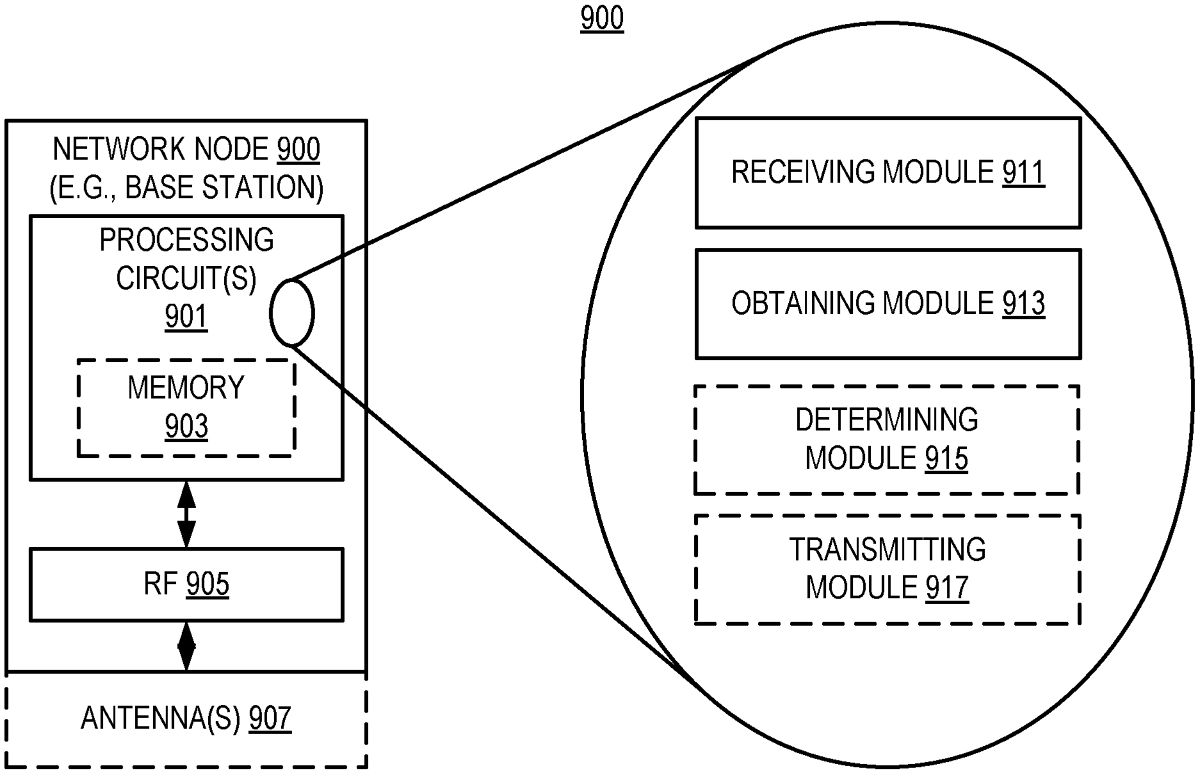
900
NETWORK NODE 900
(E.G., BASE STATION)
PROCESSING CIRCUIT(S) 901
MEMORY 903
RF 905
ANTENNA(S) 907
RECEIVING MODULE 911
OBTAINING MODULE 913
DETERMINING MODULE 915
TRANSMITTING MODULE 917

FIG. 9

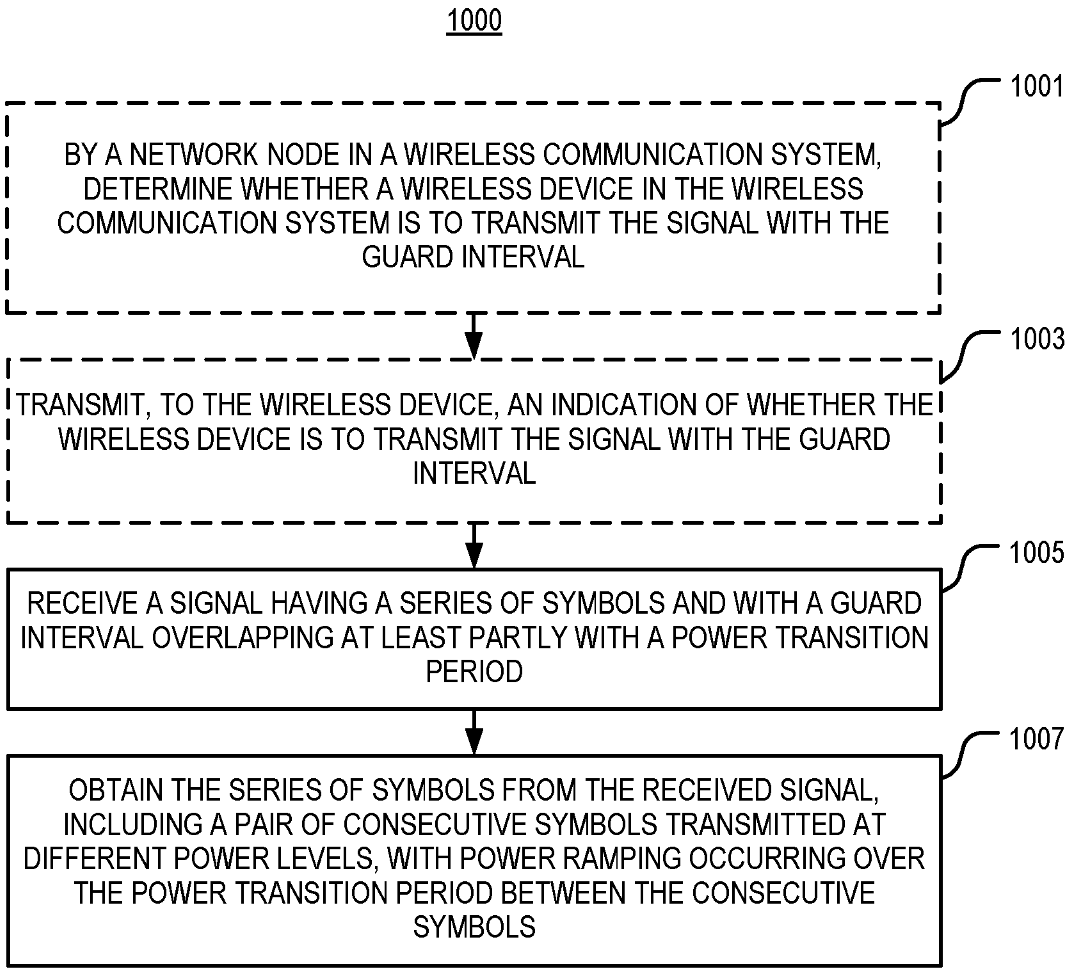
1000
1001
BY A NETWORK NODE IN A WIRELESS COMMUNICATION SYSTEM, DETERMINE WHETHER A WIRELESS DEVICE IN THE WIRELESS COMMUNICATION SYSTEM IS TO TRANSMIT THE SIGNAL WITH THE GUARD INTERVAL
1003
TRANSMIT, TO THE WIRELESS DEVICE, AN INDICATION OF WHETHER THE WIRELESS DEVICE IS TO TRANSMIT THE SIGNAL WITH THE GUARD INTERVAL
1005
RECEIVE A SIGNAL HAVING A SERIES OF SYMBOLS AND WITH A GUARD INTERVAL OVERLAPPING AT LEAST PARTLY WITH A POWER TRANSITION PERIOD
1007
OBTAIN THE SERIES OF SYMBOLS FROM THE RECEIVED SIGNAL, INCLUDING A PAIR OF CONSECUTIVE SYMBOLS TRANSMITTED AT DIFFERENT POWER LEVELS, WITH POWER RAMPING OCCURRING OVER THE POWER TRANSITION PERIOD BETWEEN THE CONSECUTIVE SYMBOLS

FIG. 10

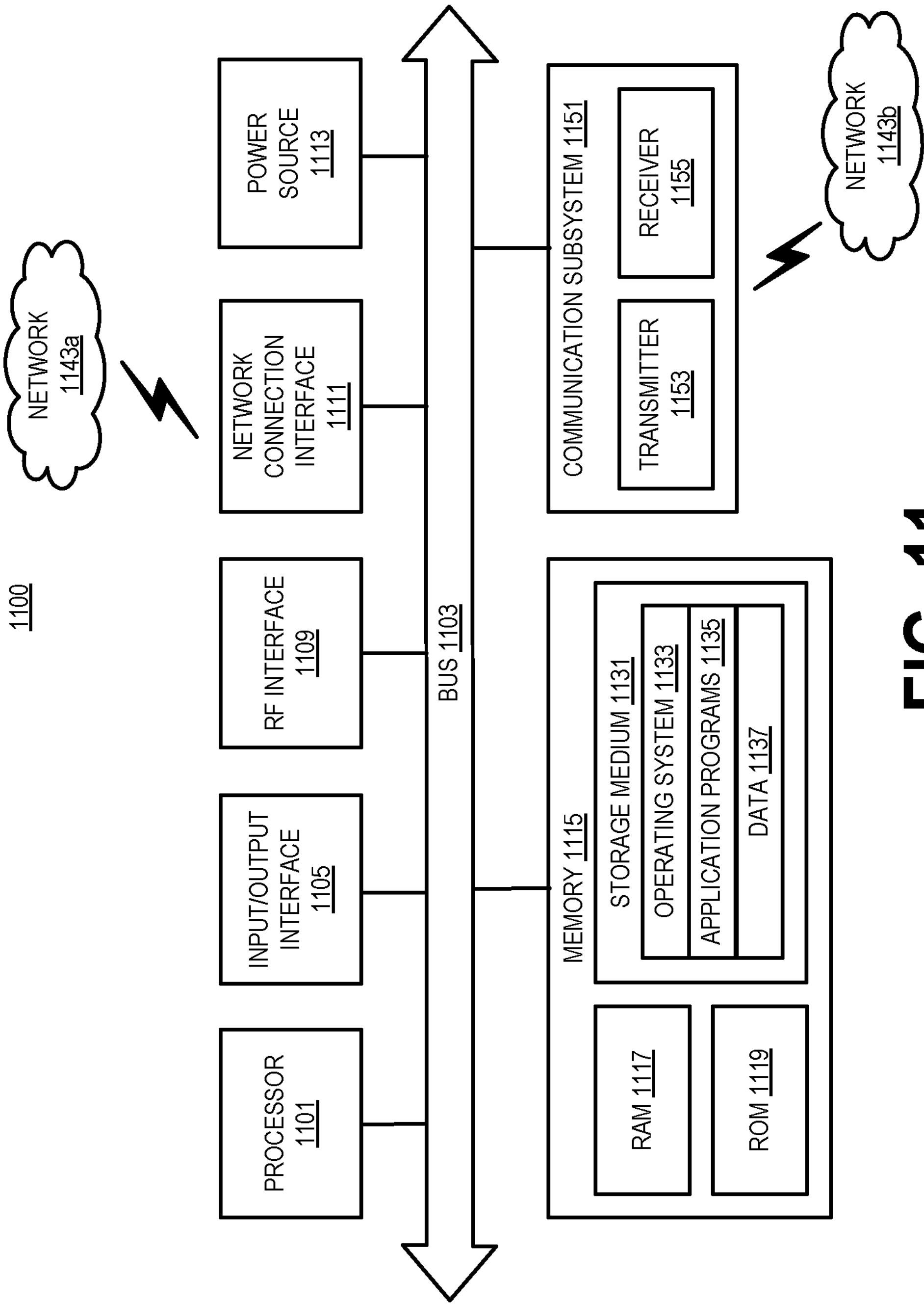
1100
NETWORK 1143a
PROCESSOR 1101
INPUT/OUTPUT INTERFACE 1105
RF INTERFACE 1109
NETWORK CONNECTION INTERFACE 1111
POWER SOURCE 1113
BUS 1103
MEMORY 1115
STORAGE MEDIUM 1131
OPERATING SYSTEM 1133
APPLICATION PROGRAMS 1135
DATA 1137
RAM 1117
ROM 1119
COMMUNICATION SUBSYSTEM 1151
TRANSMITTER 1153
RECEIVER 1155
NETWORK 1143b

FIG. 11

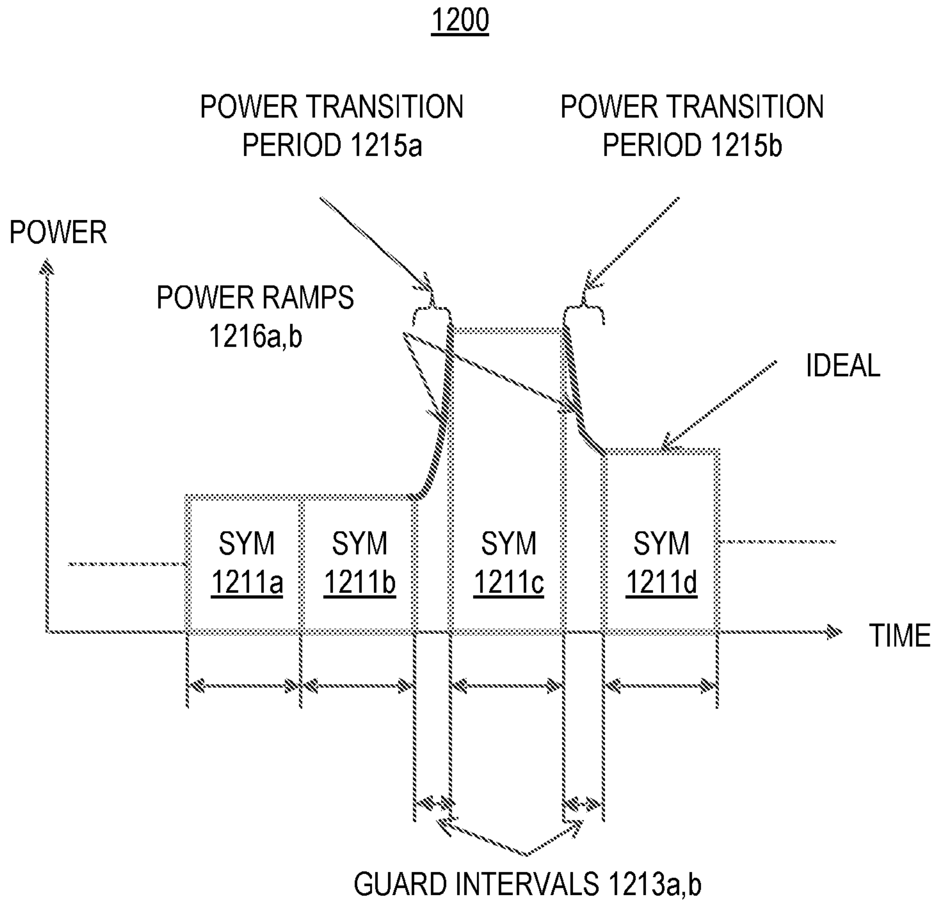
1200
POWER TRANSITION PERIOD 1215a
POWER TRANSITION PERIOD 1215b
POWER
POWER RAMPS 1216a,b
IDEAL
SYM 1211a
SYM 1211b
SYM 1211c
SYM 1211d
TIME
GUARD INTERVALS 1213a,b

FIG. 12

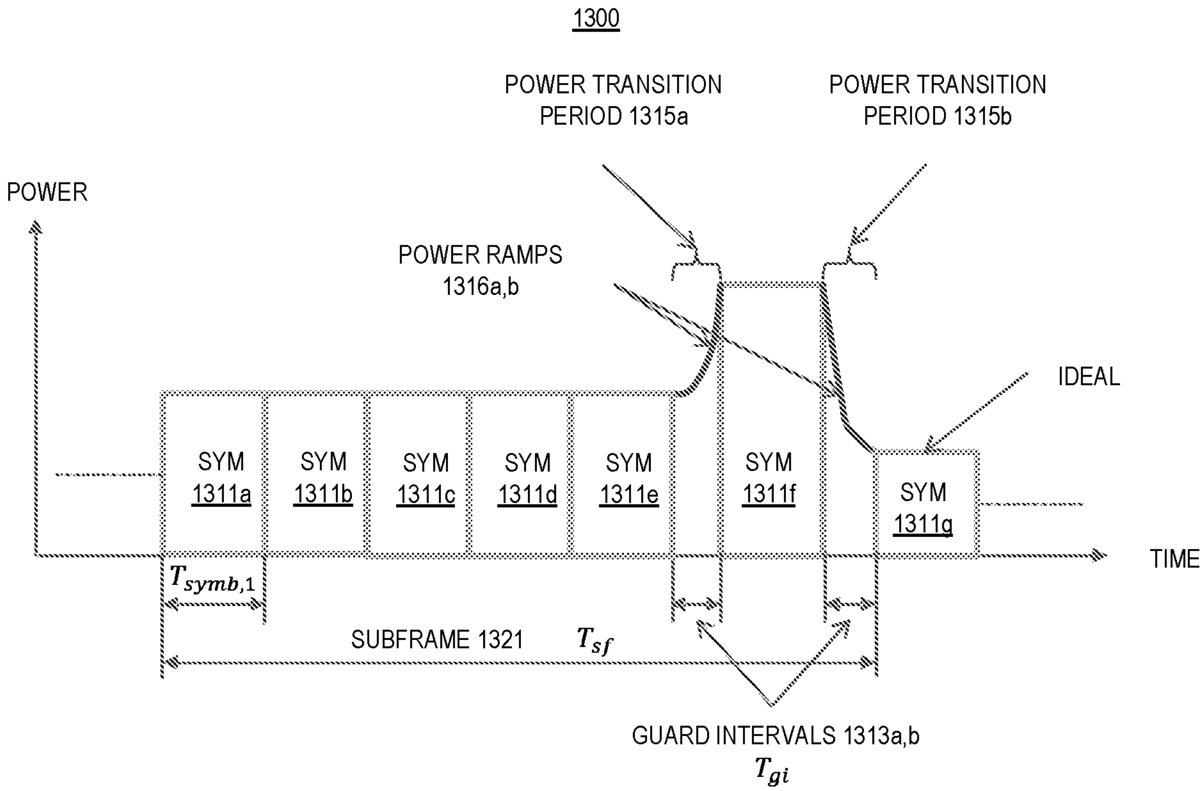
1300
POWER TRANSITION PERIOD 1315a
POWER TRANSITION PERIOD 1315b
POWER
POWER RAMPS 1316a,b
IDEAL
SYM 1311a
SYM 1311b
SYM 1311c
SYM 1311d
SYM 1311e
SYM 1311f
SYM 1311g
TIME
$T_{symb,1}$
SUBFRAME 1321 T_{sf}
GUARD INTERVALS 1313a,b
T_{gi}

FIG. 13

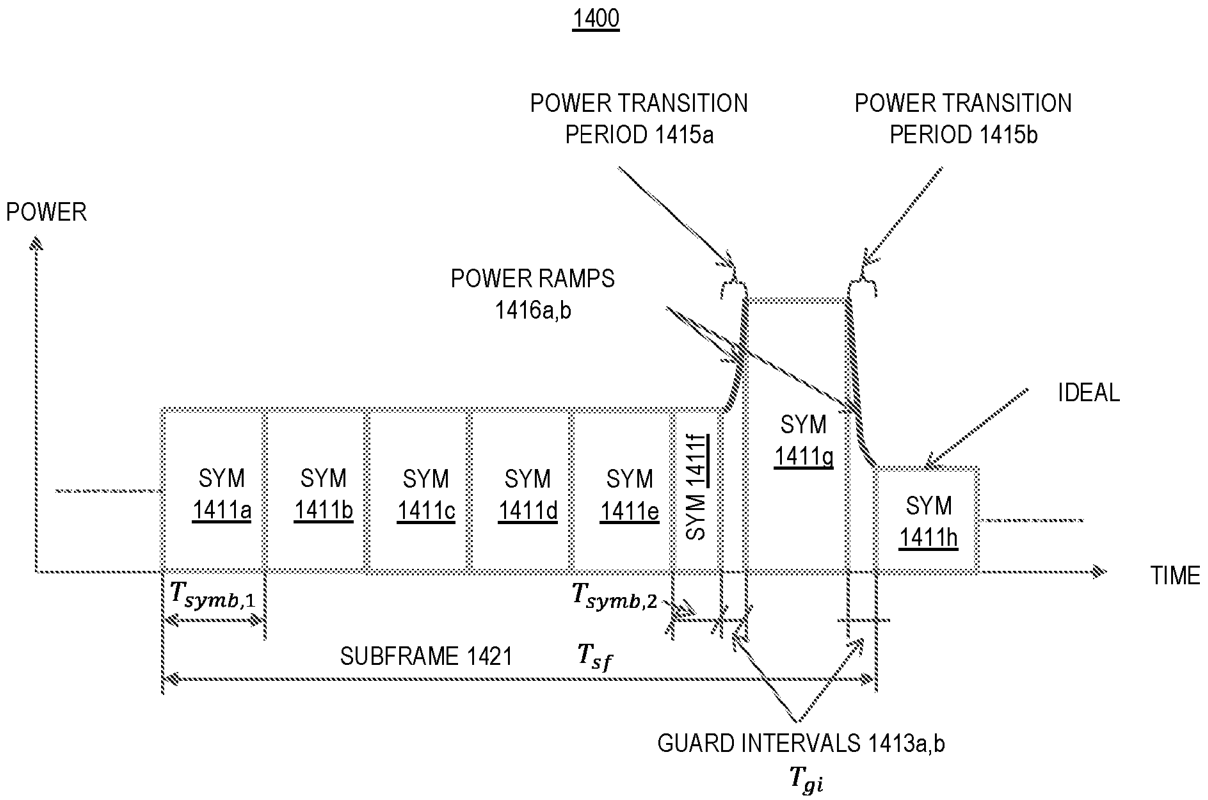
1400
POWER TRANSITION PERIOD 1415a
POWER TRANSITION PERIOD 1415b
POWER
POWER RAMPS 1416a,b
IDEAL
SYM 1411a
SYM 1411b
SYM 1411c
SYM 1411d
SYM 1411e
SYM 1411f
SYM 1411g
SYM 1411h
TIME
$T_{symb,1}$
$T_{symb,2}$
SUBFRAME 1421
T_{sf}
GUARD INTERVALS 1413a,b
T_{gi}

FIG. 14

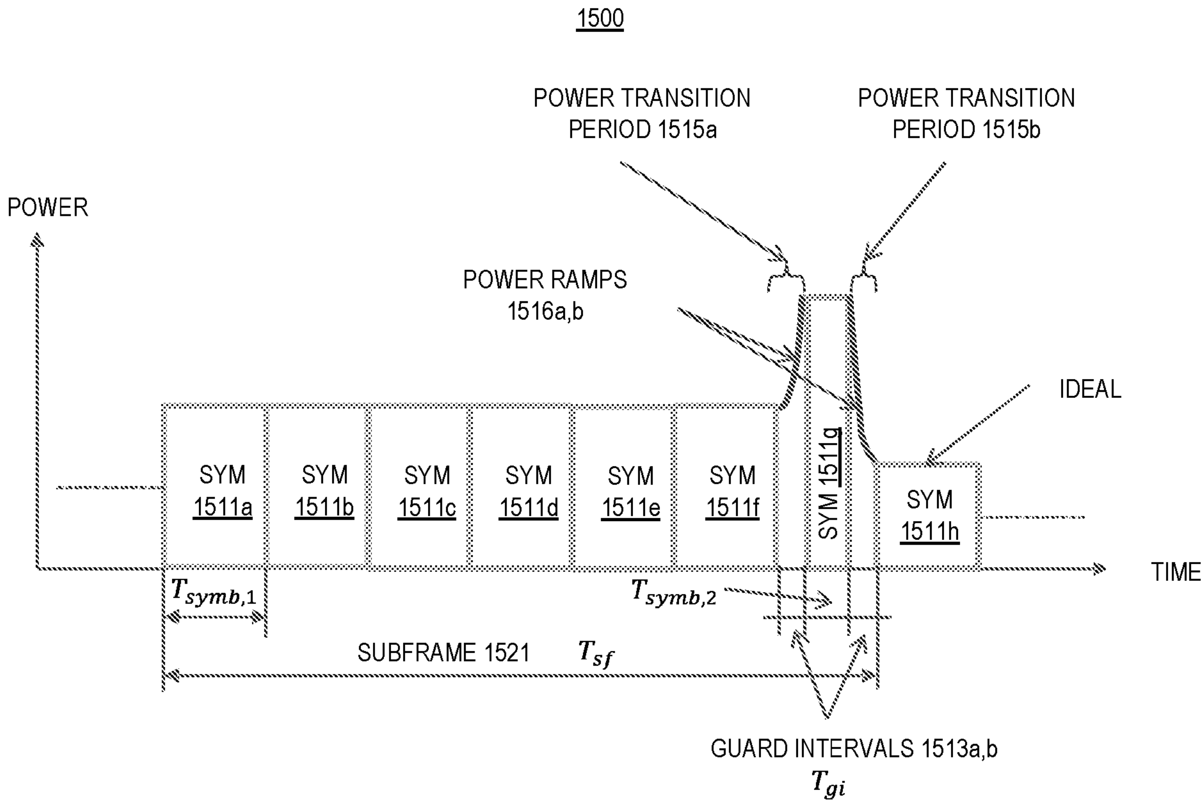
1500
POWER TRANSITION PERIOD 1515a
POWER TRANSITION PERIOD 1515b
POWER
POWER RAMPS 1516a,b
IDEAL
SYM 1511a
SYM 1511b
SYM 1511c
SYM 1511d
SYM 1511e
SYM 1511f
SYM 1511g
SYM 1511h
TIME
$T_{symb,1}$
$T_{symb,2}$
SUBFRAME 1521 T_{sf}
GUARD INTERVALS 1513a,b
T_{gi}

FIG. 15

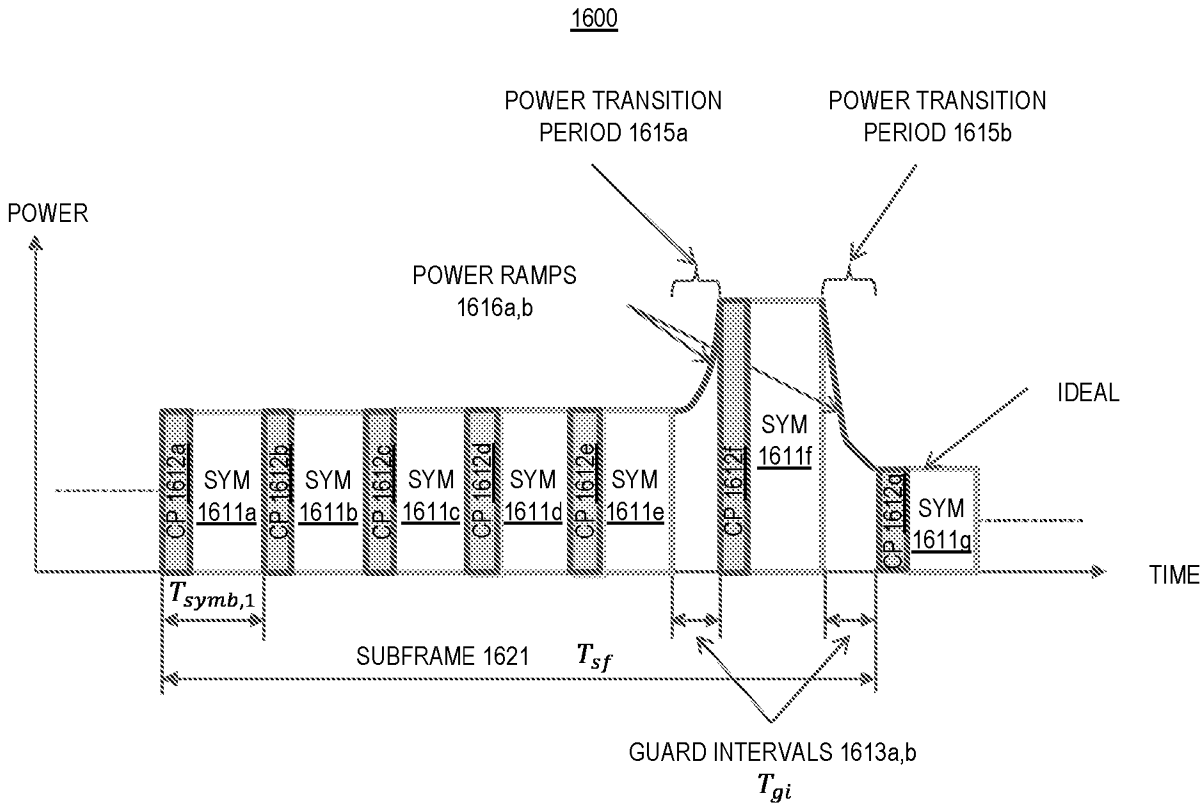
1600
POWER TRANSITION PERIOD 1615a
POWER TRANSITION PERIOD 1615b
POWER
POWER RAMPS 1616a,b
IDEAL
CP 1612a
SYM 1611a
CP 1612b
SYM 1611b
CP 1612c
SYM 1611c
CP 1612d
SYM 1611d
CP 1612e
SYM 1611e
CP 1612f
SYM 1611f
CP 1612g
SYM 1611g
TIME
$T_{symb,1}$
SUBFRAME 1621 T_{sf}
GUARD INTERVALS 1613a,b
T_{gi}

FIG. 16

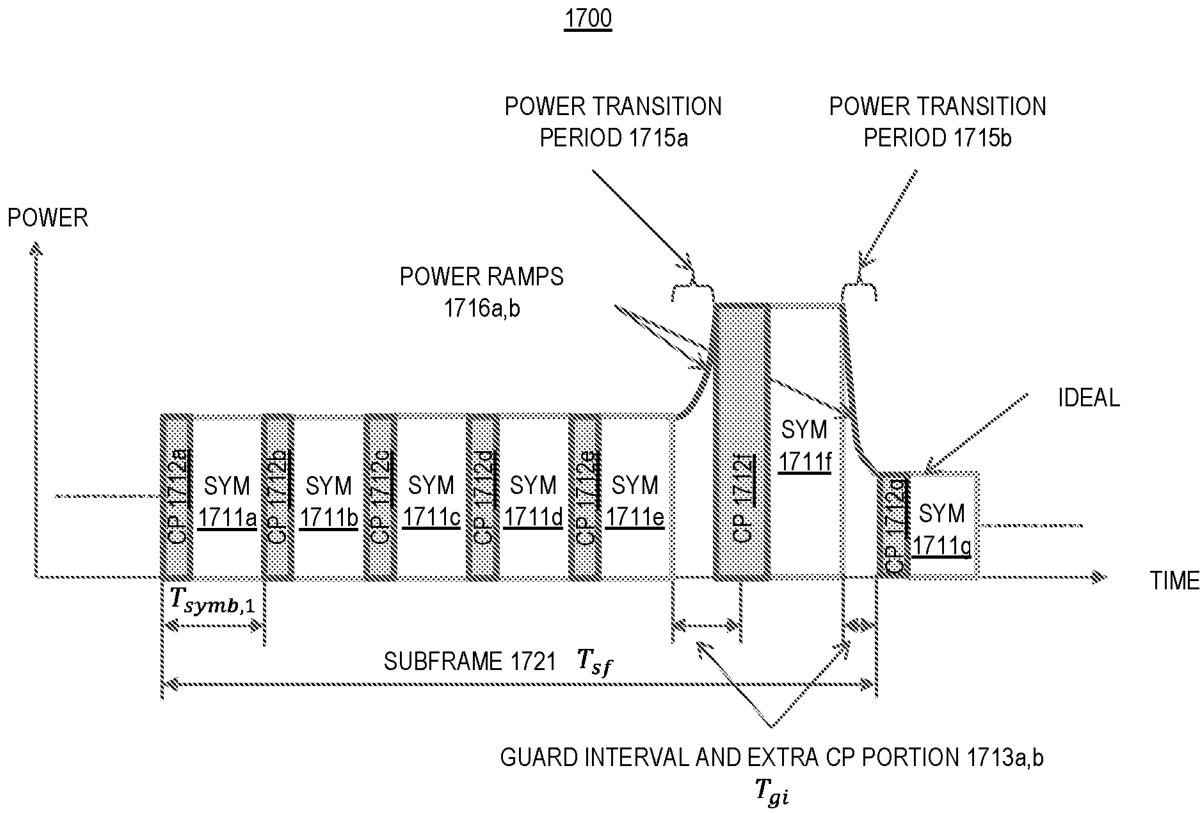
1700
POWER TRANSITION PERIOD 1715a
POWER TRANSITION PERIOD 1715b
POWER
POWER RAMPS 1716a,b
IDEAL
CP 1712a
SYM 1711a
CP 1712b
SYM 1711b
CP 1712c
SYM 1711c
CP 1712d
SYM 1711d
CP 1712e
SYM 1711e
CP 1712f
SYM 1711f
CP 1712g
SYM 1711g
TIME
$T_{symb,1}$
SUBFRAME 1721 T_{sf}
GUARD INTERVAL AND EXTRA CP PORTION 1713a,b
T_{gi}

FIG. 17

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE2017/050151

A. CLASSIFICATION OF SUBJECT MATTER

IPC: see extra sheet

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)

IPC: H04W

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE, DK, FI, NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, PAJ, WPI data, EMBASE, INSPEC

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2015047556 A1 (INTEL IP CORP), 2 April 2015 (2015-04-02); abstract; pages 6-7, 10, 13, 16-17; figures 3-5	1-9, 11-19, 21-30, 32-40, 42
A	--	10, 20, 31, 41
A	WO 2009148372 A1 (ERICSSON TELEFON AB L M ET AL), 10 December 2009 (2009-12-10); abstract; page 3 --	1-42
A	US 20060262879 A1 (SMITH ALAN A ET AL), 23 November 2006 (2006-11-23); abstract; paragraphs [0024]-[0026]; figures 3-4 -- --------	1-42

☐ 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

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"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	Date of mailing of the international search report
24-03-2017	27-03-2017

Name and mailing address of the ISA/SE	Authorized officer
Patent- och registreringsverket Box 5055 S-102 42 STOCKHOLM Facsimile No. + 46 8 666 02 86	Sanja Sain Telephone No. + 46 8 782 28 00

Continuation of: second sheet

International Patent Classification (IPC)

H04W 52/36 (2009.01)
H04W 72/04 (2009.01)

WO	2015047556 A1	02/04/2015	CN	105519228	A	20/04/2016
			CN	105519182	A	20/04/2016
			CN	105493616	A	13/04/2016
			CN	105493555	A	13/04/2016
			CN	105493554	A	13/04/2016
			CN	105493552	A	13/04/2016
			CN	105493067	A	13/04/2016
			CN	105474595	A	06/04/2016
			EP	3049955	A1	03/08/2016
			EP	3064027	A1	07/09/2016
			EP	3050395	A1	03/08/2016
			EP	3050352	A1	03/08/2016
			EP	3050350	A1	03/08/2016
			EP	3050348	A1	03/08/2016
			EP	3050345	A1	03/08/2016
			EP	3050268	A1	03/08/2016
			EP	3050227	A1	03/08/2016
			JP	2016531517	A	06/10/2016
			JP	2016532342	A	13/10/2016
			KR	20160037981	A	06/04/2016
			KR	20160027987	A	10/03/2016
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