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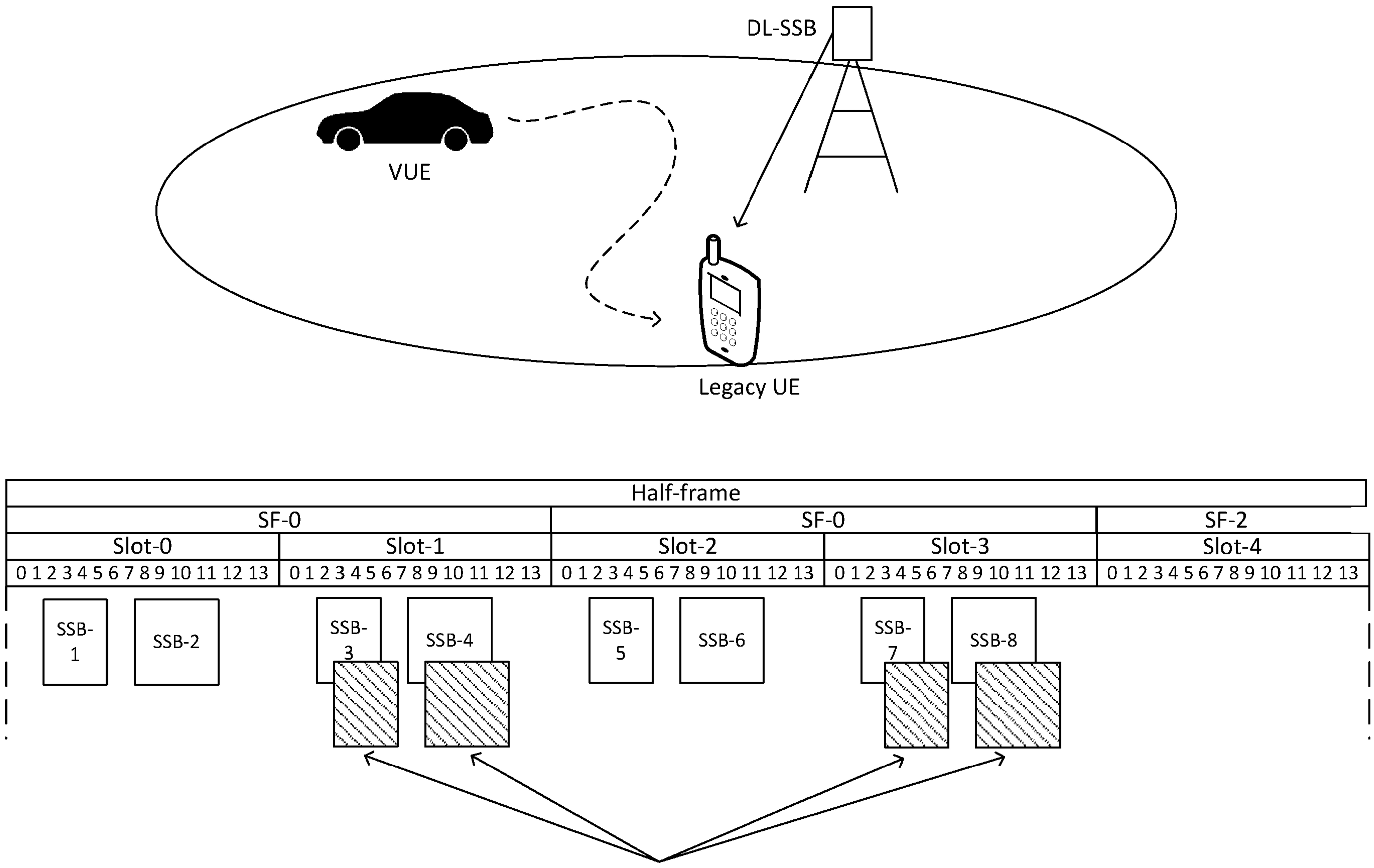


Figure 1

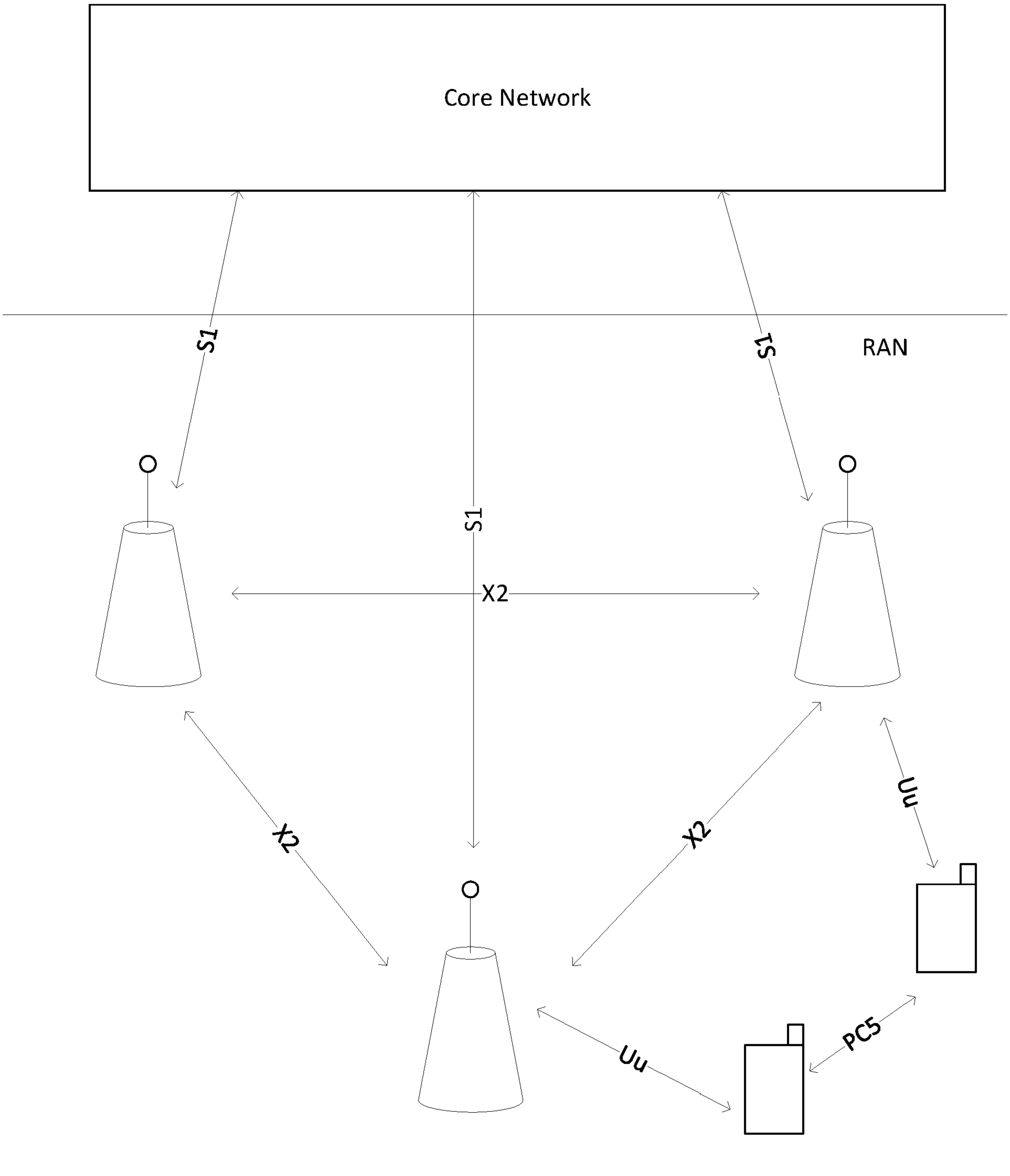


Figure 2

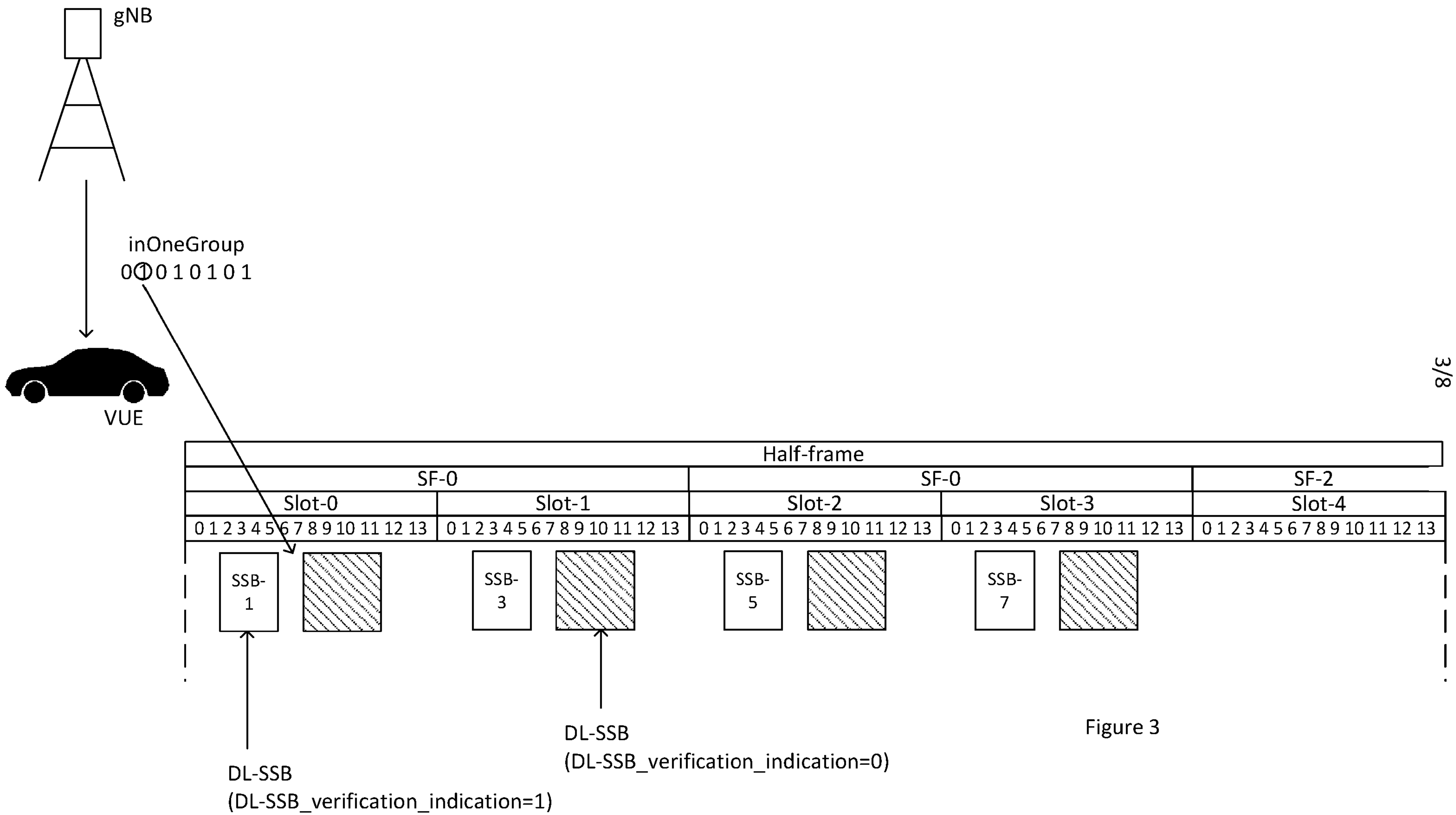
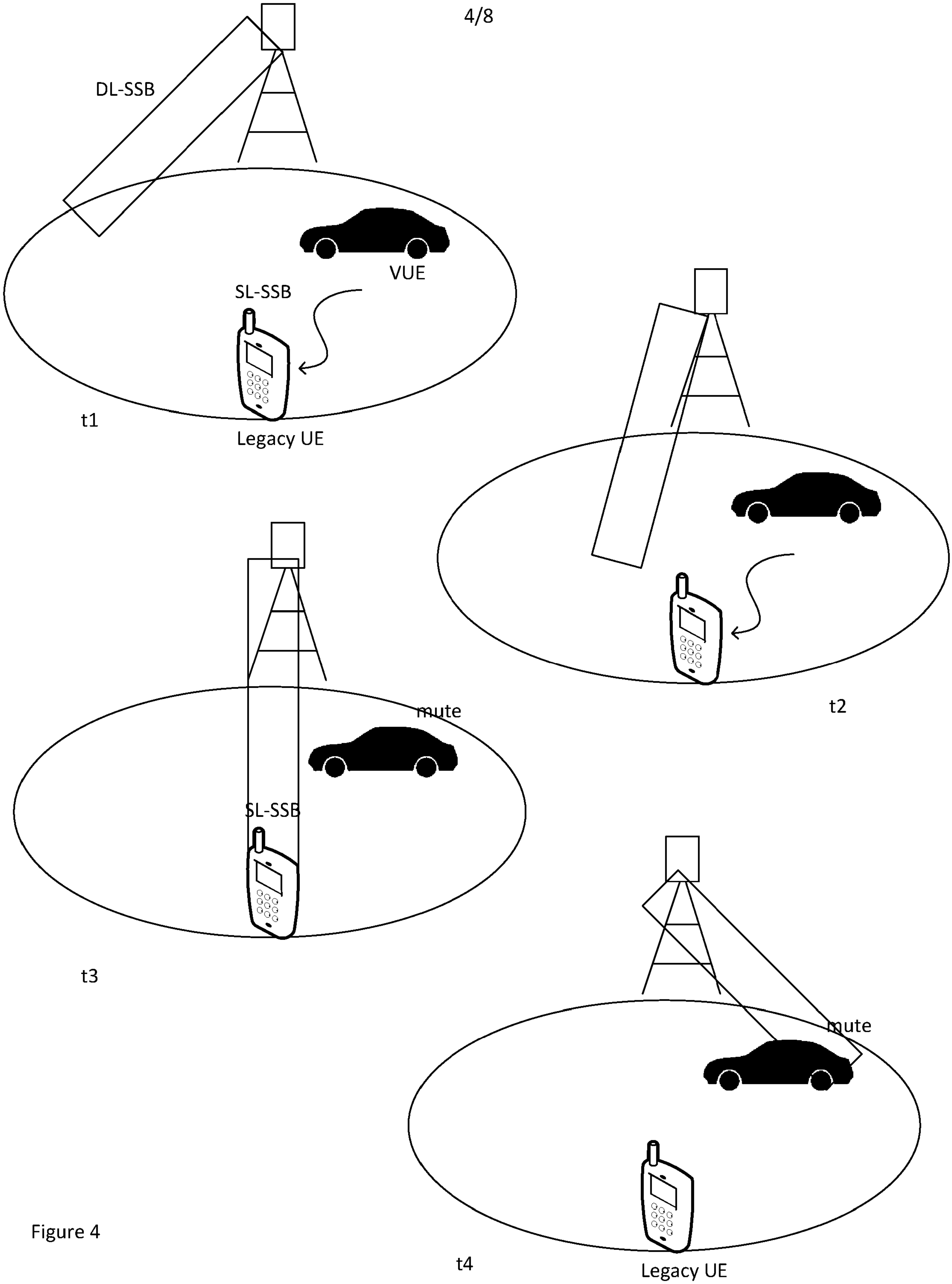

gNB
inOneGroup
0 1 0 0 1 0 1 0 1
VUE
Half-frame
SF-0
SF-0
SF-2
Slot-0
Slot-1
Slot-2
Slot-3
Slot-4
0 1 2 3 4 5 6 7 8 9 10 11 12 13
0 1 2 3 4 5 6 7 8 9 10 11 12 13
0 1 2 3 4 5 6 7 8 9 10 11 12 13
0 1 2 3 4 5 6 7 8 9 10 11 12 13
0 1 2 3 4 5 6 7 8 9 10 11 12 13
SSB-1
SSB-3
SSB-5
SSB-7
DL-SSB
(DL-SSB_verification_indication=1)
DL-SSB
(DL-SSB_verification_indication=0)

Figure 3



DL-SSB
VUE
SL-SSB
t1
Legacy UE
t2
mute
SL-SSB
t3
mute
t4
Legacy UE

Figure 4

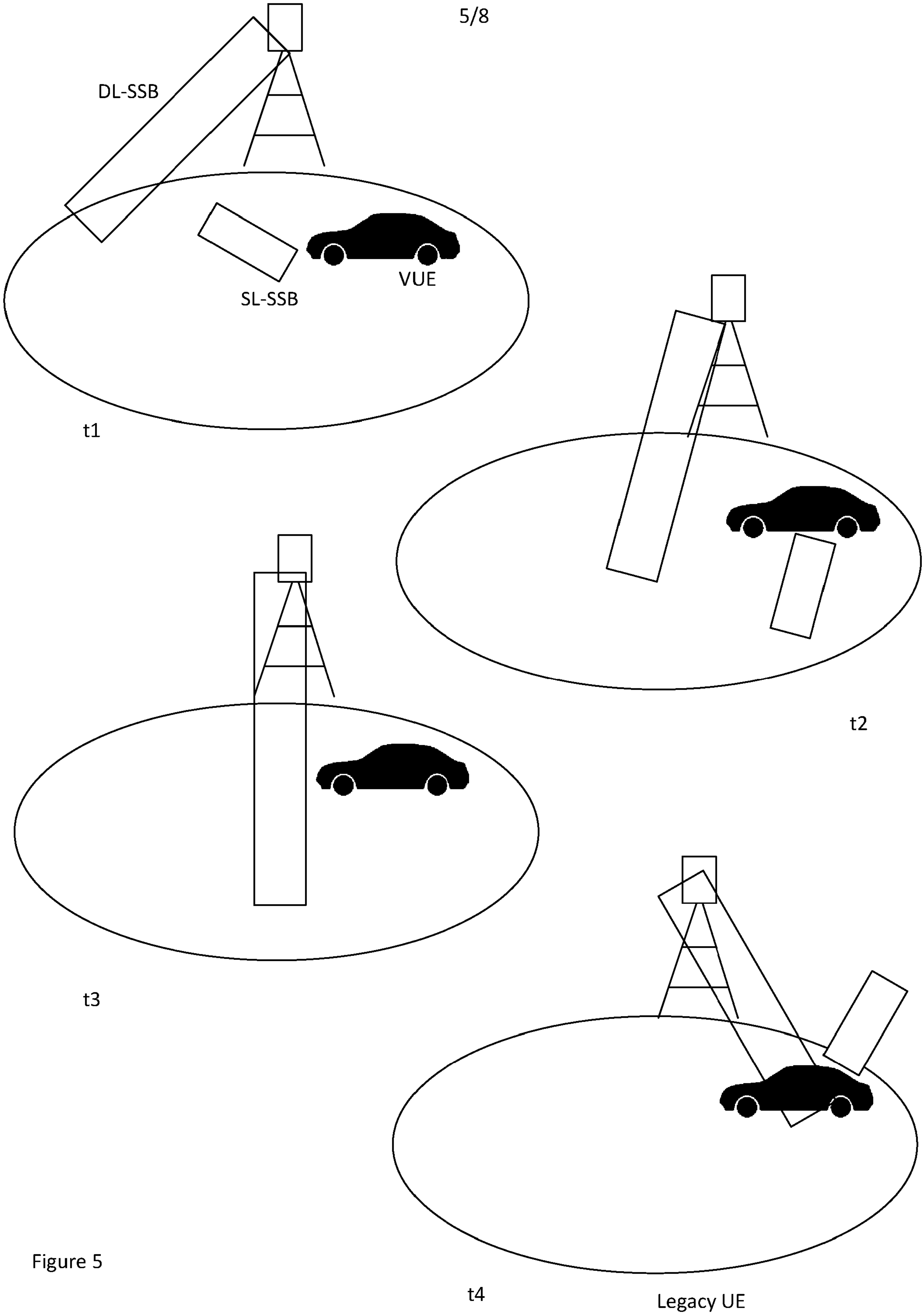


Figure 5

15 01 20

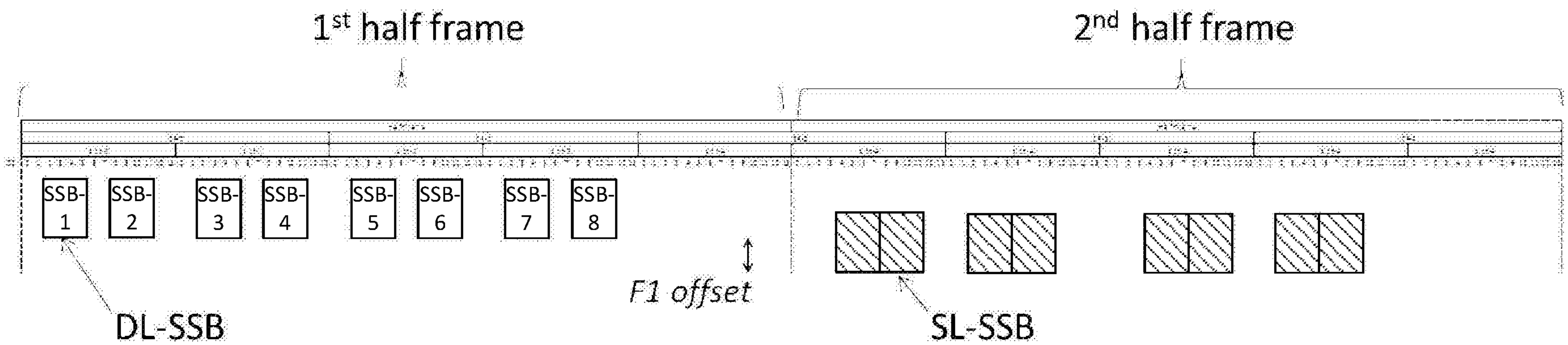


Figure 6

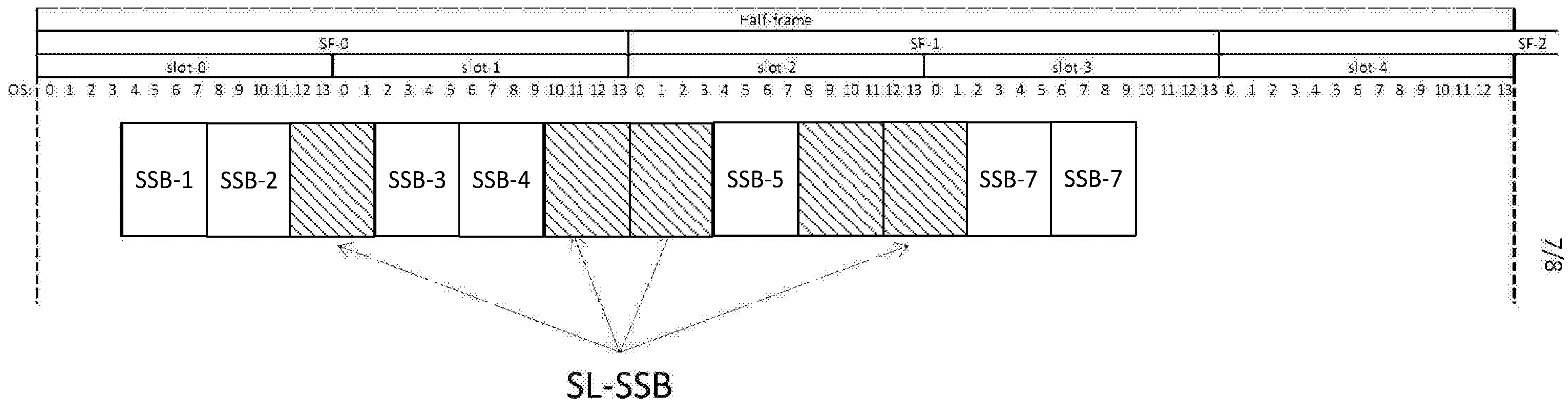

Half-frame
SF-0
SF-1
SF-2
slot-0
slot-1
slot-2
slot-3
slot-4
OS: 0 1 2 3 4 5 6 7 8 9 10 11 12 13 0 1 2 3 4 5 6 7 8 9 10 11 12 13 0 1 2 3 4 5 6 7 8 9 10 11 12 13 0 1 2 3 4 5 6 7 8 9 10 11 12 13 0 1 2 3 4 5 6 7 8 9 10 11 12 13
SSB-1
SSB-2
SSB-3
SSB-4
SSB-5
SSB-7
SSB-7
SL-SSB

Figure 7

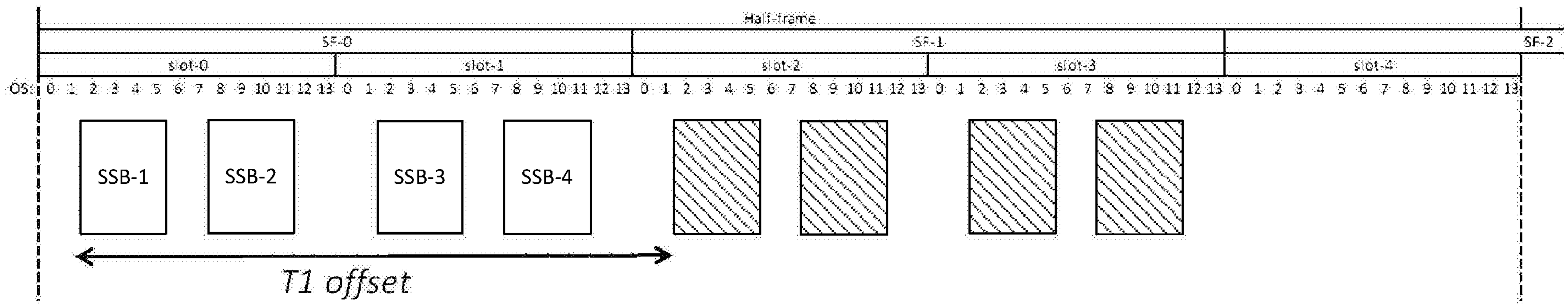

Half-frame
SF-0
SF-1
SF-2
slot-0
slot-1
slot-2
slot-3
slot-4
OS
0 1 2 3 4 5 6 7 8 9 10 11 12 13 0 1 2 3 4 5 6 7 8 9 10 11 12 13 0 1 2 3 4 5 6 7 8 9 10 11 12 13 0 1 2 3 4 5 6 7 8 9 10 11 12 13 0 1 2 3 4 5 6 7 8 9 10 11 12 13
SSB-1
SSB-2
SSB-3
SSB-4
T1 offset

Figure 8

The following terms are Registered Trade Marks and should be read as such wherever they occur in this document:

3GPP
LTE
Wi-Fi
DVD

Distinguishing Downlink Signal Synchronization Blocks and Sidelink Signal Synchronization Blocks in a Wireless Communications Network

Technical Field

[1] The following disclosure relates to distinguishing DL SSBs and SL SSBs in a Wireless Communications Network.

Background

[2] Wireless communication systems, such as the third-generation (3G) of mobile telephone standards and technology are well known. Such 3G standards and technology have been developed by the Third Generation Partnership Project (3GPP). The 3rd generation of wireless communications has generally been developed to support macro-cell mobile phone communications. Communication systems and networks have developed towards a broadband and mobile system.

[3] In cellular wireless communication systems User Equipment (UE) is connected by a wireless link to a Radio Access Network (RAN). The RAN comprises a set of base stations which provide wireless links to the UEs located in cells covered by the base station, and an interface to a Core Network (CN) which provides overall network control. As will be appreciated the RAN and CN each conduct respective functions in relation to the overall network. For convenience the term cellular network will be used to refer to the combined RAN & CN, and it will be understood that the term is used to refer to the respective system for performing the disclosed function.

[4] The 3rd Generation Partnership Project has developed the so-called Long Term Evolution (LTE) system, namely, an Evolved Universal Mobile Telecommunication System Territorial Radio Access Network, (E-UTRAN), for a mobile access network where one or more macro-cells are supported by a base station known as an eNodeB or eNB (evolved NodeB). More recently, LTE is evolving further towards the so-called 5G or NR (new radio) systems where one or more cells are supported by a base station known as a gNB. NR is proposed to utilise an Orthogonal Frequency Division Multiplexed (OFDM) physical transmission format.

[5] The NR protocols are intended to offer options for operating in unlicensed radio bands, to be known as NR-U. When operating in an unlicensed radio band the gNB and UE must compete with other devices for physical medium/resource access. For example, Wi-Fi, NR-U, and LAA may utilise the same physical resources.

[6] A trend in wireless communications is towards the provision of lower latency and higher reliability services. For example, NR is intended to support Ultra-reliable and low-latency communications (URLLC) and massive Machine-Type Communications (mMTC) are intended to provide low latency and high reliability for small packet sizes (typically 32 bytes). A user-plane latency of 1ms has been proposed with a reliability of 99.99999%, and at the physical layer a packet loss rate of 10^{-5} or 10^{-6} has been proposed. URLLC is considered for use in factory automation, the transport industry and power distribution etc. Depending on the service type, data packets may arrive sporadically or periodically.

[7] For a UE to connect to a cell provided by a base station, such as an eNB or a gNB, the UE requires information about the cell and information to allow the UE to synchronize communication with the base station. This information is provided in a Downlink (DL) signal from the base station. In LTE, the information includes primary and secondary synchronization signals

(PSS and SSS). From these signals, the UE acquires the Physical Cell ID and the time slot and frame synchronization.

[8] In NR, DL synchronization signals and a Physical Broadcast Channel (PBCH) are contained in a single block of the DL, referred to as a Synchronization Signal Block (SSB). The SSB includes a PSS, a SSS, the PBCH DMRS and the PBCH payload. The contents of the SSB are used for cell detection, coarse time/frequency DL synchronization and RRM measurements. Beam-sweeping of synchronization signals is supported in NR for enhanced coverage. One or multiple SSBs compose an SS burst. One or multiple SS bursts compose an SS burst set. There is a single SS burst set periodicity for all SSBs for a cell (the default periodicity is 5ms but this can be configured higher, up to 160ms, after initial access to the cell by the UE). The transmission of SSBs within a SS burst set is confined to a 5ms window (i.e. half-frame) regardless of the SS burst set periodicity. Each slot (e.g. 1ms time period for SCS=15kHz) can support a maximum of 2 SSB transmission opportunities and only certain slots are allowed to transmit SSBs. The maximum number, L_{max}, of SSBs in a cell SS burst set is given according to the frequency range (i.e. L_{max} = 4 up to 3GHz; L_{max} = 8 from 3 to 6GHz; L_{max} = 64 from 6 to 52.6GHz). There is a specific mapping of SSBs to symbols specified for various SCSs (15/30/120/240 kHz) and bands, defined by a SS block pattern, in order to have time candidate locations of SSBs within a slot. The SSB index ***L*** in each SSB burst set is indicated by the PBCH DMRS sequence in FR1 (f<6GHz) or by the PBCH DMRS sequence and PBCH payload in FR2 (f>6GHz). From the SSB index and the fixed time location of each SSB, a UE can achieve DL synchronization with the cell.

[9] In NR, the DL SSBs do not have to be placed to the middle of the carrier but can be transmitted in a number of possible positions in the frequency domain, referred to as the "*synchronization raster*". The sync raster indicates the frequency positions of the SSB that can be used by the UE for system acquisition when explicit signalling of the SSB position is not present (i.e. NR standalone mode). A range of global synchronization raster channels (GSCN) is defined for all NR operating bands, which is essentially a searching frequency in relatively wide steps. To allow for faster cell search and synchronization, the sync raster includes a more limited set of SSB possible frequency positions. Compared to LTE, the synchronisation signal raster in NR is increased to limit the power consumption of a UE on initial cell selection. The frequency position of a SSB is defined as SS_{REF} with a corresponding number of GSCN. A UE searches for the SSB for synchronization by scanning the frequency band with raster resolution (e.g. the UE calculates the DL received signal power, detects a set of frequency candidate positions in all supported bands and then searches for the SSB over the candidate positions). Thus the UE may attempt such blind detection multiple times to find the cell-defining SSB for synchronization. Finally, to insure at least one SSB reception, the UE has to scan the time candidates for 5ms (the SS burst set window) and average over 20ms (as for an initial cell search the UE can assume that the SSB is repeated at least once every 20ms).

[10] In addition to DL and Uplink (UL) communications between a UE and a base station, the UE may further receive communications via one or more Sidelinks (SLs). In LTE, SLs enable communication between two or more nearby devices, using E-UTRAN technology without the need for a base station. SLs provide various functions for end-to-end communication, such as distributed control and management among devices and direct communication with and without network coverage. SLs are used for several applications, such as proximity service (D2D), IoT, wearables and Vehicle to Everything (V2X) communications.

[11] In NR, there is an on-going study of V2X. NR V2X will support advanced V2X services beyond those supported in LTE. The advanced V2X services will require an enhanced NR system and new NR SL to meet the stringent requirements of this application. The NR V2X system is expected to have a flexible design to support services with low latency and high reliability

requirements. In NR V2X, SL communication can be performed in a dedicated intelligent transport system (ITS) carrier band (e.g. 5.9 GHz unlicensed band) and in an NR licensed carrier band (e.g. mmWave frequency bands around 30 GHz and 63 GHz). The most likely spectrum to be available for V2X in practice is 5.9GHz in FR1 and 63GHz in FR2.

[12] SL communications require a synchronization mechanism and this is one of the aspects of NR SL design being studied. This includes details of synchronization sources and procedures, synchronization channel structure, design principles, synchronization signals, waveform, numerology etc. One of the requirements of a NR SL synchronization mechanism, for V2X and other applications, is the protection of UEs from out-of-coverage UEs when DL and SL licensed carriers overlap. It is essential to ensure good co-existence between SL and DL SSB transmissions. Where there is overlapping between the NR licensed band for DL and the NR SL band, for initial access to a cell, a UE will be searching for DL SSBs using a sync raster and if SL SSBs are also transmitted in the same cell by other UEs, e.g. Vehicle UEs (VUEs), there is the risk of interference with DL SSBs. The UE may experience confusion with regard to received SSBs (see Figure 1). Such confusion can lead to incorrect soft-combining of DL SSBs and SL SSBs, access delay, and can destroy the UE initial cell access procedure.

Summary

[13] This Summary is provided to introduce a selection of concepts in a simplified form that are further described below in the Detailed Description. This Summary is not intended to identify key features or essential features of the claimed subject matter, nor is it intended to be used as an aid in determining the scope of the claimed subject matter.

[14] A method is proposed of distinguishing downlink (DL) signal synchronization blocks (SSBs) and sidelink (SL) SSBs in a wireless communications network comprising at least one base station, at least one first user equipment (UE), at least one second UE, a SL between the first UE and the second UE and a DL between the base station and the second UE, the method comprising, in the base station, configuring a group of candidate SSB positions in a SSB burst set for transmission of SSBs, specifying a subgroup of candidate SSB positions for DL SSBs, specifying a remaining subgroup as a subgroup of candidate SSB positions for SL SSBs, transmitting an indication of the subgroup of candidate SSB positions for SL SSBs to the first UE, and transmitting an indication of the subgroup of candidate SSB positions for DL SSBs to the second UE, in the first UE, using the indication of the subgroup of candidate SSB positions for SL SSBs to configure the first UE to transmit SL SSBs on the subgroup of candidate SSB positions, and in the second UE, using the indication of the subgroup of candidate SSB positions for DL SSBs to distinguish DL SSBs received from the base station and SL SSBs received from the first UE.

[15] The indication of the subgroup of candidate SSB positions for SL SSBs may comprise the candidate SSB positions for SL SSBs described by a field in a system information block (SIB) received by the first UE. The indication of the subgroup of candidate SSB positions for SL SSBs may comprise the candidate SSB positions for SL SSBs characterised by RRC signalling received by the first UE.

[16] The indication of the subgroup of candidate SSB positions for DL SSBs may comprise the candidate SSB positions for DL SSBs described by a field in a SIB received by the second UE. The indication of the subgroup of candidate SSB positions for DL SSBs may comprise the candidate SSB positions for DL SSBs described by RMSI received by the second UE. The

indication of the subgroup of candidate SSB positions for DL SSBs may comprise the candidate SSB positions for DL SSBs described in a PBCH/PSBCH-MIB received by the second UE. The indication of the subgroup of candidate SSB positions for DL SSBs may comprise identification of DL SSBs by a field introduced within each DL SSB received by the second UE. The indication of the subgroup of candidate SSB positions for SL SSBs may be transmitted to the second UE and may comprise identification of SL SSBs by a field introduced within each SL SSB received by the second UE.

[17] A method is proposed of distinguishing downlink (DL) signal synchronization blocks (SSBs) and sidelink (SL) SSBs in a wireless communications network comprising a first base station defining a first cell, a second base station defining a second cell, at least one first user equipment (UE) located at an edge of the first cell and at least one second UE located in the second cell, the method comprising cooperation of the first and second base stations to exchange DL SSB and SL SSB transmission information.

[18] A method is proposed of distinguishing downlink (DL) signal synchronization blocks (SSBs) and sidelink (SL) SSBs in a wireless communications network comprising at least one base station, at least one first user equipment (UE), at least one second UE, a SL between the first UE and the second UE and a DL between the base station and the second UE where there is beam-sweeping of the DL SSBs, the method comprising, in the base station, configuring a group of candidate SSB positions in a SSB burst set for transmission of SSBs, sharing the group of candidate SSB positions between SL SSBs and DL SSBs, and in the first UE, prioritizing DL SSB transmission on shared candidate SSB positions by muting SL SSB transmission on the shared candidate SSB positions.

[19] The first UE may mute SL SSB transmission on the shared candidate SSB positions by receiving a DL SSB beaming pattern from the base station, using the beaming pattern to perform transmission strength measurements of expected DL SSB transmissions and muting SL SSB transmissions that collide in time or frequency with a predefined number of strongest DL SSB transmissions or with DL SSB transmissions whose strength exceeds a predefined value. The second UE may be able to beam SL SSBs and aligns its SL SSB beaming pattern with the DL SSB beaming pattern in order to reduce interference between DL SSBs and SL SSBs.

[20] A method is proposed of distinguishing downlink (DL) signal synchronization blocks (SSBs) and sidelink (SL) SSBs in a wireless communications network comprising at least one base station, at least one first user equipment (UE), at least one second UE, a SL between the first UE and the second UE and a DL between the base station and the second UE, the method comprising, in the base station, multiplexing candidate SSB positions for DL SSBs and candidate SSB positions for SL SSBs in the time domain within a frame structure by allocating candidate SSB positions for the DL SSBs in a first half frame and candidate SSB positions for the SL SSBs in a second half frame with a fixed frequency offset between the DL SSBs and the SL SSBs, transmitting the frame structure and DL SSBs to the second UE, in the first UE, transmitting SL SSBs to the second UE, and in the second UE, using the frame structure for candidate SSB position allocations and the fixed frequency offset to determine if a received SSB is located in the first half frame or the second half frame, thereby distinguishing between DL SSBs and SL SSBs.

[21] A method is proposed of distinguishing downlink (DL) signal synchronization blocks (SSBs) and sidelink (SL) SSBs in a wireless communications network comprising at least one base station, at least one first user equipment (UE), at least one second UE, a SL between the first UE and the second UE and a DL between the base station and the second UE, the method comprising, in the base station, multiplexing candidate SSB positions for DL SSBs and candidate SSB positions for SL SSBs in the time domain within a frame structure using a first pattern for allocating candidate SSB positions for the DL SSBs in a half frame and using a second pattern for

allocating candidate SSB positions for the SL SSBs in the same half frame, transmitting the frame structure and DL SSBs to the second UE, in the first UE, transmitting SL SSBs to the second UE, and in the second UE, using the frame structure for candidate SSB position allocations and extra received SSBs within the half frame to distinguish between DL SSBs and SL SSBs.

[22] A method is proposed of distinguishing downlink (DL) signal synchronization blocks (SSBs) and sidelink (SL) SSBs in a wireless communications network comprising at least one base station, at least one first user equipment (UE), at least one second UE, a SL between the first UE and the second UE and a DL between the base station and the second UE, the method comprising, in the base station, configuring the SL SSB transmissions on off-raster frequency positions in the frequency domain, in the first UE, transmitting the SL SSB transmissions together with an indication of the off-raster frequency position offset to the second UE, and in the second UE, using the indication of the off-raster frequency position offset to realise the SL SSB received at an off-raster frequency position and improve detection of on-raster DL SSBs transmitted from the base station.

[23] The first UE may be a vehicle UE. The second UE may be a legacy UE.

[24] The non-transitory computer readable medium may comprise at least one from a group consisting of: a hard disk, a CD-ROM, an optical storage device, a magnetic storage device, a Read Only Memory, a Programmable Read Only Memory, an Erasable Programmable Read Only Memory, EPROM, an Electrically Erasable Programmable Read Only Memory and a Flash memory.

Brief description of the drawings

[25] Further details, aspects and embodiments of the invention will be described, by way of example only, with reference to the drawings. Elements in the figures are illustrated for simplicity and clarity and have not necessarily been drawn to scale. Like reference numerals have been included in the respective drawings to ease understanding.

[26] Figure 1 shows SL SSB interference with DL SSB.

[27] Figure 2 shows a schematic diagram of a cellular network.

[28] Figure 3 shows use by SL SSBs of free candidate SSB positions of the SSB burst set configured for a first UE.

[29] Figure 4 shows prioritizing DL SSB transmission on shared candidate SSB positions by muting SL SSB transmission on the shared positions.

[30] Figure 5 shows aligning of a SL SSB beaming pattern with a DL SSB beaming pattern.

[31] Figure 6 shows using a fixed frequency offset between DL SSBs in a first half frame and SL SSBs in a second half frame.

[32] Figure 7 shows using a first pattern for placing DL SSBs in a half frame and using a second pattern for placing SL SSBs in the same half frame.

[33] Figure 8 shows using the same patterns for DL SSBs and SL SSBs and specifying a predefined time pattern offset for the SL SSBs.

Detailed description of the preferred embodiments

[34] Those skilled in the art will recognise and appreciate that the specifics of the examples described are merely illustrative of some embodiments and that the teachings set forth herein are applicable in a variety of alternative settings.

[35] Figure 2 shows a schematic diagram of three base stations (for example, eNB or gNBs depending on the particular cellular standard and terminology) forming a cellular network. Typically, each of the base stations will be deployed by one cellular network operator to provide geographic coverage for UEs in the area. The base stations form a Radio Area Network (RAN). Each base station provides wireless coverage for UEs in its area or cell. The base stations are interconnected via the X2 interface and are connected to the core network via the S1 interface. As will be appreciated only basic details are shown for the purposes of exemplifying the key features of a cellular network.

[36] The base stations each comprise hardware and software to implement the RAN's functionality, including communications with the core network and other base stations, carriage of control and data signals between the core network and UEs, and maintaining wireless communications with UEs associated with each base station. The core network comprises hardware and software to implement the network functionality, such as overall network management and control, and routing of calls and data.

[37] In a wireless communications network, in the case of a shared carrier band, i.e. overlapping between the licensed DL carrier band and a SL carrier band, between UEs, such as a NR Uu (DL/UL) UE and a NR PC5 (SL) UE, , a UE should be able to distinguish the synchronization signals transmitted from the two different interfaces, i.e. distinguish DL SSBs and SL SSBs. Otherwise misunderstanding of received SSBs may cause problems. A number of approaches are proposed for distinguishing between DL SSBs and SL SSBs considering that improvement is needed in aspects such as flexibility, latency, search complexity and interference between DL SSBs and SL SSBs.

[38] In a wireless communications network comprising at least one base station, at least one first UE, at least one second UE, a SL between the first UE and the second UE and a DL between the base station and the second UE, in a first embodiment, the method of distinguishing DL SSBs and SL SSBs comprises in the base station, configuring a group of candidate SSB positions in a SSB burst set for transmission of SSBs, specifying a subgroup of candidate SSB positions for DL SSBs, specifying a remaining subgroup as a subgroup of candidate SSB positions for SL SSBs, transmitting an indication of the subgroup of candidate SSB positions for SL SSBs to the first UE, and transmitting an indication of the subgroup of candidate SSB positions for DL SSBs to the second UE, in the first UE, using the indication of the subgroup of candidate SSB positions for SL SSBs to configure the first UE to transmit SL SSBs on the subgroup of candidate SSB positions, and in the second UE, using the indication of the subgroup of candidate SSB positions for DL SSBs to distinguish DL SSBs received from the base station and SL SSBs received from the first UE.

[39] The first UE is therefore configured to use free candidate SSB positions of the SSB burst set configured for the first UE (see Figure 3). To realise such use, an indication of the free, or remaining, SSB positions not specified for DL SSBs is sent to the first UE so that the UE can be configured to use the free SSB positions to transmit SL SSBs. Candidate SSB positions are free when a base station employs less than the maximum number of SSB positions for DL SSBs. This may be the case for example when a) the required coverage of the cell can be satisfied with a low number of SSBs, b) the cell desires to reduce DL sync control overhead, and/or c) UEs in the cell, due to limited capability, can monitor only a limited number of SSB positions (less than the configured maximum number of DL SSBs).

[40] The candidate SSB positions for DL SSBs can be described by a field in a SIB received by the second UE. In one embodiment, the field (*ssb-Positioninburst*) comprises two 8-bit bitmaps. The first bitmap (*groupPresence*) indicates the groups of 8 SSB positions which are used for DL SSBs (first bit is for DL SSB positions with indexes 0 to 7, second bit is for DL SSB positions with indexes 8 to 15, etc). This bitmap is only applicable for FR2 (i.e. in the case where L_{max}=64). The second bitmap (*inOneGroup*) indicates the SSB positions within each group used for transmitting DL SSBs.

[41] Similarly, the candidate SSB positions for SL SSBs can be described by a field in a SIB received by the first UE. The field (*SL-ssb-Positioninburst*) could reuse the format of the *ssb-Positioninburst* field. Alternatively the format could be modified (e.g. to denote in which SSB positions not to transmit SL SSBs). Indication of the candidate SSB positions for SL SSBs to the first UE is not delay sensitive as it is not needed for initial access of the first UE to the cell, but just to inform the already-connected first UE which SSB position resources to use for SL SSBs. Greater flexibility on the *SL-ssb-Positioninburst* field for FR2 on resource allocation could be designed to make possible multiplexing of SL SSBs from different first UEs/SL sources. For this reason, a single 64-bit bitmap could be used for the *SL-ssb-Positioninburst* field. This field could be obtained during RRC sync reconfiguration and could also be provided in a unicast (per first UE) or groupcast (per group of first UEs) manner, even via dynamic indication, e.g. DCI, to achieve more flexibility on SL SSB transmissions within the cell.

[42] The candidate SSB positions for DL SSBs can be received by the second UE by using conventional RMSI. However, with such an approach, the second UE will become aware that an received SSB is a DL SSB or not, only after the SIB is properly decoded. This will cause delay in the case of initial access of the second UE to the cell. At the same time, decoding the SL SSB will not have been a complete waste for the first UE as it will be possible to use the information that is same between DL SSBs and SL SSBs (e.g. information for coarse time/frequency synchronization, and in MIB for system timing, initial access).

[43] DL SSBs can be identified by a field introduced within each DL SSB received by the second UE. SL SSBs can be identified by a field introduced within each SL SSB received by the second UE. The fields may comprise 1 bit and allow the second UE to clarify a SSB type upon detecting / decoding it.

[44] The candidate SSB positions for DL SSBs can be described in a PBCH/PSBCH-MIB received by the second UE. The MIB may have a spare bit which could be used for a *DL SSB verification indication* field and the content of the bit could be e.g. 1 for DL SSBs, 0 for SL SSBs. The DL SSB verification indication bit can also be communicated instead via a SIB, via PBCH-DMRS, PSS/PSSS or SSS/SSSS so that the second UE can differentiate between DL SSBs and SL SSBs before decoding the broadcast channel. For example, those who are skilled in the relevant art can consider a mask on top of SSS sequences, or adding new scrambling values to scramble the SSS M-sequence or PSBCH, or using a different initialization for the DMRS-PBCH scrambling sequence generator.

[45] This approach to distinguishing DL SSBs and SL SSBs has minimum impact on SSB specification and on SSB interference to UEs. However, it can work only when the total number of required SSBs is less than the specified maximum number of SSBs.

[46] The use of the DL SSB positions in the SSB burst set for transmitting SL SSBs will optimise SSB resource efficiency, make possible multiplexing with DL SSBs when a carrier cannot accommodate more resources in frequency / time, reduce the first UE complexity, maximise the reuse of the existing timing acquisition circuit, reduce the need to search for

multiple SSBs over frequency at the same time, avoid a long and power-intensive sync search procedure, make possible use of short SSB burst periodicity, such as 5ms.

[47] In a wireless communications network comprising a first base station defining a first cell, a second base station defining a second cell, at least one first user equipment (UE) located at an edge of the first cell and at least one second UE located in the second cell a second embodiment of a method of distinguishing DL SSBs and SL SSBs comprises cooperation of the first and second base station to exchange DL SSB and SL SSB transmission information.

[48] The DL SSB and SL SSB transmission information may be exchanged via a backhaul link. This method avoids inter-cell interference.

[49] In a wireless communications network comprising at least one base station, at least one first UE, at least one second UE, a SL between the first UE and the second UE and a DL between the base station and the second UE where there is beam-sweeping of the DL SSBs, a third embodiment of a method of distinguishing DL SSBs and SL SSBs comprises in the base station, configuring a group of candidate SSB positions in a SSB burst set for transmission of SSBs and sharing the group of candidate SSB positions between SL SSBs and DL SSBs, and in the first UE, prioritizing DL SSB transmission on shared candidate SSB positions by muting SL SSB transmission on the shared candidate SSB positions (see Figure 4).

[50] The first UE may mute SL SSB transmission on the shared candidate SSB positions by receiving a DL SSB beaming pattern from the base station, using the beaming pattern to perform transmission strength measurements of expected DL SSB transmissions and muting SL SSB transmissions that collide in time or frequency with the strongest measured DL SSB transmissions. The DL SSB beaming pattern can be retrieved at the first UE by signalling similar to the *ssb-Positioninburst* field in the SIB. The muting operation can be configured by the base station. A pre-defined number of muted SL SSB transmissions or a pre-defined strength value for DL SSB transmissions to be prioritized could be configured by the network.

[51] When the first UE is able to beam SL SSBs, it may align its SL SSB beaming pattern with the DL SSB beaming pattern in order to reduce interference between DL SSBs and SL SSBs. The first UE may align its SL SSB beaming pattern autonomously or by network configuration (see Figure 5).

[52] When the above embodiments of the invention are not possible (e.g. no free candidate SSB positions, no beam-sweeping) or are not efficient (e.g. not enough free candidate SSB positions, S-SSB muting is inefficient), time division multiplexing (TDM) can be considered to orthogonalize DL SSBs and SL SSBs. In doing so, the periodicity should not be limited; at least the minimum option of 5ms periodicity should be possible for SL SSBs.

[53] In a wireless communications network comprising at least one base station, at least one first UE, at least one second UE, a SL between the first UE and the second UE and a DL between the base station and the second UE, in a fourth embodiment, a method of distinguishing DL SSBs and SL SSBs comprises in the base station, multiplexing candidate SSB positions for DL SSBs and candidate SSB positions for SL SSBs in the time domain within a frame structure by allocating candidate SSB positions for the DL SSBs in a first half frame and candidate SSB positions for the SL SSBs in a second half frame with a fixed frequency offset between the DL SSBs and the SL SSBs, transmitting the frame structure and DL SSBs to the second UE, in the first UE, transmitting SL SSBs to the second UE, and in the second UE, using the frame structure for candidate SSB position allocations and the fixed frequency offset to determine if a received SSB is located in the first half frame or the second half frame, thereby distinguishing between DL SSBs and SL SSBs.

[54] The fixed frequency offset, preconfigured to the second UE, between the DL SSBs and the SL SSBs (see Figure 6), allows the second UE to know if it is detecting in the first half frame or the second half frame. The second UE, upon receiving DL SSBs and SL SSBs will be able to distinguish between them.

[55] In a wireless communications network comprising at least one base station, at least one first UE, at least one second UE, a SL between the first UE and the second UE and a DL between the base station and the second UE, a fifth embodiment of a method of distinguishing DL SSBs and SL SSBs comprises in the base station, multiplexing candidate SSB positions for DL SSBs and candidate SSB positions for SL SSBs in the time domain within a frame structure using a first pattern for allocating candidate SSB positions for the DL SSBs in a half frame and using a second pattern for allocating candidate SSB positions for the SL SSBs in the same half frame, transmitting the frame structure and DL SSBs to the second UE, in the first UE, transmitting SL SSBs to the second UE, and in the second UE, using the frame structure for candidate SSB position allocations and extra received SSBs within the half frame to distinguish between DL SSBs and SL SSBs.

[56] It would be possible to specify SL SSB specific patterns (configured to the first UE in a cell by the base station) that are orthogonal or partially orthogonal (yet, with low correlation to DL SSBs) in time with DL SSBs. Figure 7 provides such an example for a possible new SL SSB specific pattern of Lmax=4, which could fit orthogonally with 8 DL SSBs using pattern-B in “3<f<6GHz, SCS=30kHz” case. The second UE could identify DL SSBs from SL SSBs by figuring out the extra received SSBs within a half frame and/or the unexpected positions in time between received SSBs (or by using again a fixed frequency offset for S-SSBs as before).

[57] Alternatively, the same patterns for DL SSBs and SL SSBs could be used. A predefined time pattern offset could be specified for SL SSBs (and indicated to the first UE) to TDM with DL SSBs within a half-frame (see Figure 8).

[58] The multiplexing in the time domain, within half frames, makes it possible to configure short SSB burst set periodicity, such as 5 ms, to reduce the latency introduced by orthogonal partitioning of resources in time, to avoid the impact from employing other solutions, UE complexity with FDM, different sequences / SSB structure.

[59] A method is proposed of distinguishing downlink (DL) signal synchronization blocks (SSBs) and sidelink (SL) SSBs in a wireless communications network comprising at least one base station, at least one first user equipment (UE), at least one second UE, a SL between the first UE and the second UE and a DL between the base station and the second UE, the method comprising, in the base station, configuring the SL SSB transmissions on off-raster frequency positions in the frequency domain, in the first UE transmitting the SL SSB transmissions together with an indication of the off-raster frequency position offset to the second UE, and at the second UE, using the indication of the off-raster frequency position offset to realise the SL SSB received at an off-raster frequency position and improve detection of on-raster DL SSBs transmitted from the base station.

[60] The purpose is to enhance initial access procedure of a non-PC5 UE, when it is able to detect/decode SL SSBs, so as to find DL SSBs faster when scanning in frequency at a given time.

[61] Configuring the SL SSB transmission on off-raster position in the frequency domain will reduce interference with DL SSBs at the second UE. Extremely time-consuming synchronization procedures can also be avoided by reducing the number of SL SSB hypotheses.

[62] However, even off-raster SSBs may be detected by a non-PC5 UE that is searching for its first synchronization source. To avoid mistaking SL SSBs for DL SSBs in a non-PC5 UE, detecting SL SSBs at off-raster positions MIB content i.e. PSSS, SSSS or PSBCH of a SL SSB could be used to help UEs perform initial access for detecting on-raster DL SSBs. For example, an off-raster frequency position offset indicator could be included. When understood by a non-PC5 UE, it could be realised that this is an off-raster frequency or even some coarse frequency information could be attained.

[63] Although not shown in detail any of the devices or apparatus that form part of the network may include at least a processor, a storage unit and a communications interface, wherein the processor unit, storage unit, and communications interface are configured to perform the method of any aspect of the present invention. Further options and choices are described below.

[64] The signal processing functionality of the embodiments of the invention especially the gNB and the UE may be achieved using computing systems or architectures known to those who are skilled in the relevant art. Computing systems such as, a desktop, laptop or notebook computer, hand-held computing device (PDA, cell phone, palmtop, etc.), mainframe, server, client, or any other type of special or general purpose computing device as may be desirable or appropriate for a given application or environment can be used. The computing system can include one or more processors which can be implemented using a general or special-purpose processing engine such as, for example, a microprocessor, microcontroller or other control module.

[65] The computing system can also include a main memory, such as random access memory (RAM) or other dynamic memory, for storing information and instructions to be executed by a processor. Such a main memory also may be used for storing temporary variables or other intermediate information during execution of instructions to be executed by the processor. The computing system may likewise include a read only memory (ROM) or other static storage device for storing static information and instructions for a processor.

[66] The computing system may also include an information storage system which may include, for example, a media drive and a removable storage interface. The media drive may include a drive or other mechanism to support fixed or removable storage media, such as a hard disk drive, a floppy disk drive, a magnetic tape drive, an optical disk drive, a compact disc (CD) or digital video drive (DVD) read or write drive (R or RW), or other removable or fixed media drive. Storage media may include, for example, a hard disk, floppy disk, magnetic tape, optical disk, CD or DVD, or other fixed or removable medium that is read by and written to by media drive. The storage media may include a computer-readable storage medium having particular computer software or data stored therein.

[67] In alternative embodiments, an information storage system may include other similar components for allowing computer programs or other instructions or data to be loaded into the computing system. Such components may include, for example, a removable storage unit and an interface , such as a program cartridge and cartridge interface, a removable memory (for example, a flash memory or other removable memory module) and memory slot, and other removable storage units and interfaces that allow software and data to be transferred from the removable storage unit to computing system.

[68] The computing system can also include a communications interface. Such a communications interface can be used to allow software and data to be transferred between a computing system and external devices. Examples of communications interfaces can include a modem, a network interface (such as an Ethernet or other NIC card), a communications port (such as for example, a universal serial bus (USB) port), a PCMCIA slot and card, etc. Software and data transferred via a communications interface are in the form of signals which can be

electronic, electromagnetic, and optical or other signals capable of being received by a communications interface medium.

[69] In this document, the terms ‘computer program product’, ‘computer-readable medium’ and the like may be used generally to refer to tangible media such as, for example, a memory, storage device, or storage unit. These and other forms of computer-readable media may store one or more instructions for use by the processor comprising the computer system to cause the processor to perform specified operations. Such instructions, generally 45 referred to as ‘computer program code’ (which may be grouped in the form of computer programs or other groupings), when executed, enable the computing system to perform functions of embodiments of the present invention. Note that the code may directly cause a processor to perform specified operations, be compiled to do so, and/or be combined with other software, hardware, and/or firmware elements (e.g., libraries for performing standard functions) to do so.

[70] The non-transitory computer readable medium may comprise at least one from a group consisting of: a hard disk, a CD-ROM, an optical storage device, a magnetic storage device, a Read Only Memory, a Programmable Read Only Memory, an Erasable Programmable Read Only Memory, EPROM, an Electrically Erasable Programmable Read Only Memory and a Flash memory. In an embodiment where the elements are implemented using software, the software may be stored in a computer-readable medium and loaded into computing system using, for example, removable storage drive. A control module (in this example, software instructions or executable computer program code), when executed by the processor in the computer system, causes a processor to perform the functions of the invention as described herein.

[71] Furthermore, the inventive concept can be applied to any circuit for performing signal processing functionality within a network element. It is further envisaged that, for example, a semiconductor manufacturer may employ the inventive concept in a design of a stand-alone device, such as a microcontroller of a digital signal processor (DSP), or application-specific integrated circuit (ASIC) and/or any other sub-system element.

[72] It will be appreciated that, for clarity purposes, the above description has described embodiments of the invention with reference to a single processing logic. However, the inventive concept may equally be implemented by way of a plurality of different functional units and processors to provide the signal processing functionality. Thus, references to specific functional units are only to be seen as references to suitable means for providing the described functionality, rather than indicative of a strict logical or physical structure or organisation.

[73] Aspects of the invention may be implemented in any suitable form including hardware, software, firmware or any combination of these. The invention may optionally be implemented, at least partly, as computer software running on one or more data processors and/or digital signal processors or configurable module components such as FPGA devices.

[74] Thus, the elements and components of an embodiment of the invention may be physically, functionally and logically implemented in any suitable way. Indeed, the functionality may be implemented in a single unit, in a plurality of units or as part of other functional units. Although the present invention has been described in connection with some embodiments, it is not intended to be limited to the specific form set forth herein. Rather, the scope of the present invention is limited only by the accompanying claims. Additionally, although a feature may appear to be described in connection with particular embodiments, one skilled in the art would recognise that various features of the described embodiments may be combined in accordance with the invention. In the claims, the term ‘comprising’ does not exclude the presence of other elements or steps.

[75] Furthermore, although individually listed, a plurality of means, elements or method steps may be implemented by, for example, a single unit or processor. Additionally, although individual features may be included in different claims, these may possibly be advantageously combined, and the inclusion in different claims does not imply that a combination of features is not feasible and/or advantageous. Also, the inclusion of a feature in one category of claims does not imply a limitation to this category, but rather indicates that the feature is equally applicable to other claim categories, as appropriate.

[76] Furthermore, the order of features in the claims does not imply any specific order in which the features must be performed and in particular the order of individual steps in a method claim does not imply that the steps must be performed in this order. Rather, the steps may be performed in any suitable order. In addition, singular references do not exclude a plurality. Thus, references to ‘a’, ‘an’, ‘first’, ‘second’, etc. do not preclude a plurality.

[77] Although the present invention has been described in connection with some embodiments, it is not intended to be limited to the specific form set forth herein. Rather, the scope of the present invention is limited only by the accompanying claims. Additionally, although a feature may appear to be described in connection with particular embodiments, one skilled in the art would recognise that various features of the described embodiments may be combined in accordance with the invention. In the claims, the term ‘comprising’ or “including” does not exclude the presence of other elements.

Claims

1. A method of distinguishing downlink (DL) signal synchronization blocks (SSBs) and sidelink (SL) SSBs in a wireless communications network comprising at least one base station, at least one first user equipment (UE), at least one second UE, a SL between the first UE and the second UE and a DL between the base station and the second UE, the method comprising,
in the base station,
configuring a group of candidate SSB positions in a SSB burst set for transmission of SSBs,
specifying a subgroup of candidate SSB positions for DL SSBs,
specifying a remaining subgroup as a subgroup of candidate SSB positions for SL SSBs,
transmitting an indication of the subgroup of candidate SSB positions for SL SSBs to the first UE, and
transmitting an indication of the subgroup of candidate SSB positions for DL SSBs to the second UE,
in the first UE,
using the indication of the subgroup of candidate SSB positions for SL SSBs to configure the first UE to transmit SL SSBs on the subgroup of candidate SSB positions, and
in the second UE,
using the indication of the subgroup of candidate SSB positions for DL SSBs to distinguish DL SSBs received from the base station and SL SSBs received from the first UE.

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2. A method according to claim 1 in which the indication of the subgroup of candidate SSB positions for SL SSBs comprises the candidate SSB positions for SL SSBs described by a field in a system information block (SIB) received by the first UE.

3. A method according to claim 1 in which the indication of the subgroup of candidate SSB positions for SL SSBs comprises the candidate SSB positions for SL SSBs characterised by RRC signalling received by the first UE.

4. A method according to any preceding claim in which the indication of the subgroup of candidate SSB positions for DL SSBs comprises the candidate SSB positions for DL SSBs described by a field in a SIB received by the second UE.

5. A method according to any of claims 1 to 3 in which the indication of the subgroup of candidate SSB positions for DL SSBs comprises the candidate SSB positions for DL SSBs described by RMSI received by the second UE.

6. A method according to any of claims 1 to 3 in which the indication of the subgroup of candidate SSB positions for DL SSBs comprises the candidate SSB positions for DL SSBs described in a PBCH/PSBCH-MIB received by the second UE.

7. A method according to any of claims 1 to 3 in which the indication of the subgroup of candidate SSB positions for DL SSBs comprises identification of DL SSBs by a field introduced within each DL SSB received by the second UE.

8. A method according to any preceding claim in which the indication of the subgroup of candidate SSB positions for SL SSBs is transmitted to the second UE and comprises identification of SL SSBs by a field introduced within each SL SSB received by the second UE.