

Exhibit B

Exhibit B**T-Mobile's Infringement of The '477 Patent**

T-Mobile directly infringes the '477 patent—either literally or under the doctrine of equivalents—by making, using, selling, offering for sale, and/or importing into the United States T-Mobile's Infringing Instrumentalities, which are covered by claims 1-20 of the '477 patent ("Asserted Claims"). General Access contends that each limitation of the Asserted Claims is literally present in T-Mobile's Infringing Instrumentalities. To the extent that any limitation is not literally present, General Access contends that it is present under the doctrine of equivalents. T-Mobile's Infringing Instrumentalities that General Access has identified to date are listed in these infringement contentions.

General Access contends that any other T-Mobile products made, used, sold, offered for sale, and/or imported into the United States during the relevant period, and that operated similarly to the accused 4G and 5G Products, also infringe the '477 patent. General Access reserves the right to update these contentions, and its list of Infringing Instrumentalities, as discovery progresses. T-Mobile has aggressively touted its use of 5G technology and leadership in the 5G arena:

T-Mobile Rules the World for 5G Availability and 5G Reach. In a new global report, leading research firm Opensignal today confirmed that T-Mobile (NASDAQ: TMUS) customers get a 5G signal more often and in more places than anyone else on the planet. [S]aid Neville Ray, President of Technology at T-Mobile[,] "[w]e're out in front of the competition, and we're not looking back."

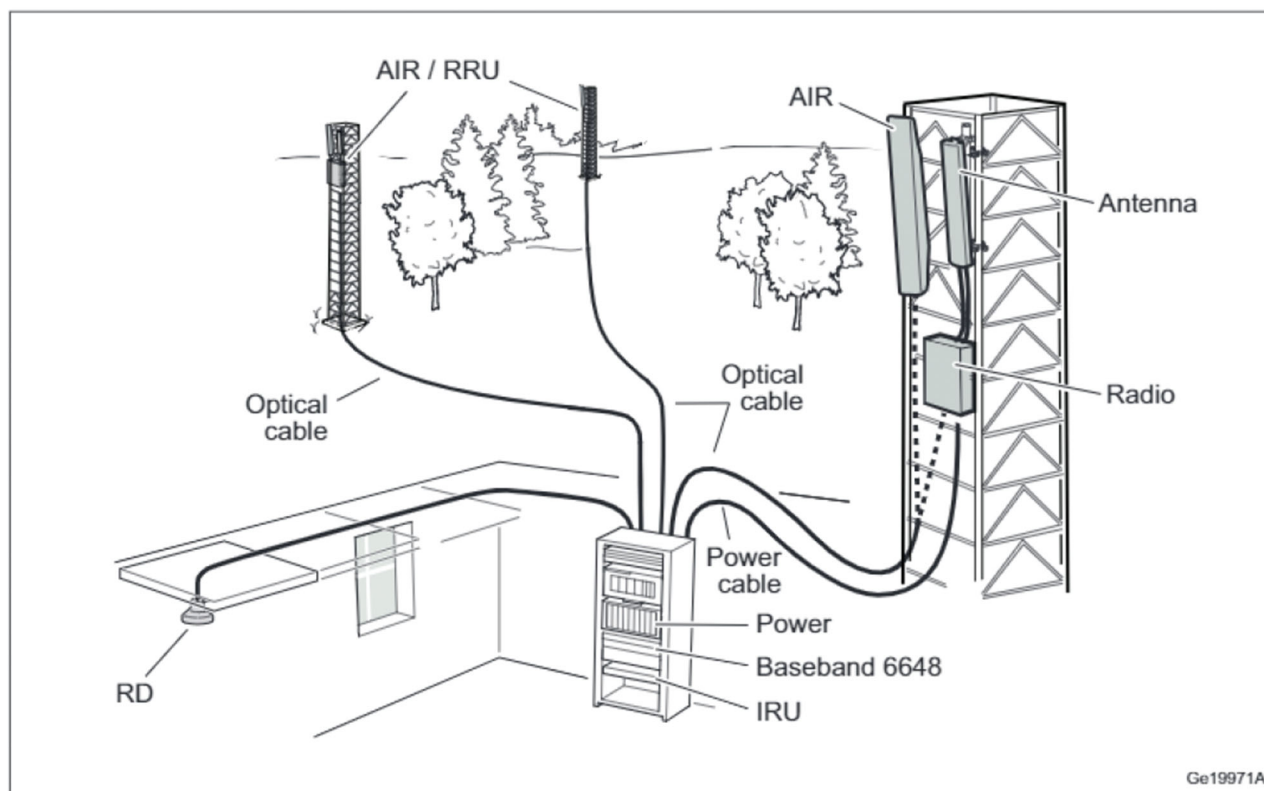
<https://www.t-mobile.com/news/network/t-mobile-rules-the-world-for-5g-availability-and-reach> (Sep. 20, 2022).

5G is the next generation of wireless technology, designed to expand the scope of mobile technology beyond the capabilities of LTE. It will fuel innovation across every industry and transform every aspect of our lives. Over time, 5G technology will change the way we live, work, and play—for the better.

<https://www.t-mobile.com/5g#:~:text=What%20does%205G%20UC%20mean,5G%20and%20Ultra%20Capacity%205G>. ("What is 5G Technology")

T-Mobile has also aggressively touted its leadership in 4G LTE. *See, e.g.* <https://www.t-mobile.com/resources/what-is-lte>; <https://www.t-mobile.com/coverage/extended-range-compatible-devices>.

Claims	Infringement Contentions
1. Profile-creating apparatus for creating at least a first profile associated with transmission upon at least a first channel of at least a first burst-data signal transmitted in bursts to a receiving station, said profile-creating apparatus comprising:	To the extent that the preamble is limiting, T-Mobile 4G and 5G base stations include a profile-creating apparatus for creating at least a first profile associated with transmission upon at least a first channel of at least a first burst-data signal transmitted in bursts to a receiving station. For example, and without limitation T-Mobile’s 4G and 5G base stations comprise a receiving station operable to receive a transmission upon at least a first channel of at least a first burst-data signal transmitted in bursts to a receiving station. <i>See, e.g.</i>, https://www.t-mobile.com/coverage/4g-lte-5g-networks (touting the benefits of T-Mobile’s 5G network, including that it “covers 325 million Americans nationwide”). <i>See also</i> https://www.t-mobile.com/news/network/americas-leading-wireless-network-tops-competitors-in-new-report (touting the same 325 million figure, and noting T-Mobile’s network speed); https://www.t-mobile.com/news/network/tmobile-5g-claims-more-third-party-report-wins (T-Mobile news release regarding “umlaut” report finding that T-Mobile had the fastest uplink speeds in 5G). T-Mobile 4G and 5G base stations include antennas, baseband units, air interface units, and additional hardware and software. For example, and without limitation, the following image depicts some of the hardware that may be included in a base station utilizing an Ericsson BBU:



See Ericsson Baseband Description, Baseband 6648, 6641. (retrieved from <https://studylib.net/doc/25912867/baseband-6641-6648-description>). See also <https://www.coursehero.com/file/142380780/ts-t-mobile-025-211006-dcltr-CheshireStdoc/> (Transcend Wireless application for T-Mobile station including Ericsson 6648 BBU). A base station like the one depicted above can alternatively utilize equipment from other manufacturers, including but not limited to Samsung, Nokia, Commscope, and others. See, e.g., <https://www.nokia.com/about-us/news/releases/2023/02/28/nokia-qualcomm-and-t-mobile-achieve-industry-first-5g-carrier-aggregation-combining-5-component-carriers-mwc23/> (discussing T-Mobile's use of Nokia base station equipment); <https://www.nokia.com/networks/radio-access-networks/> (more detailed descriptions of Nokia base stations).

Regardless of the specific equipment deployed, all T-Mobile 4G and 5G base stations are operable to receive a transmission upon at least a first channel of at least a first burst-data signal transmitted in bursts to a receiving station. Subscriber stations transmit data to T-Mobile's 4G and 5G base stations in "packets." *Id.* at Introduction, liv – lv (discussing packet transmissions in 3GPP). Packet data traffic is transmitted in bursts. See, e.g., Dahlman 4G at 335 (noting that "[p]acket-data traffic is often highly bursty"); see also Ahmadi, 5G NR at Introduction, liv – lv (discussing the "transmission time intervals" in 3GPP, and noting that "data on a transport channel is organized into transport blocks"). The profile creating apparatus is generally depicted in the figure below as the "Scheduler" block (drawn in the red box), and it resides in the T-Mobile base station. The Scheduler generates settings for, among others, re-transmission control (including coding), modulation, and antenna and resource assignments, which includes time/frequency resource mapping and precoding. 3GPP Evolved Universal Terrestrial Radio Access (E-UTRA, more commonly known as LTE), is a standard for mobile phones used worldwide, intended to support interoperation between mobile handsets and T-Mobile base stations. Mobile phone handsets which conform to the LTE standard include the ability to communicate with the base station, while the base station uses such communications to employ its profile-creating capability.

Signals transmitted from a T-Mobile base station ("eNodeB" in 4G; "gNodeB" in 5G) to a mobile handset (User Equipment or "UE"), are done so over a downlink ("DL"). Signals are transmitted from the UE to the base station over an uplink ("UL"). The base station may calculate signal and channel related information based on reference signals transmitted in the uplink. The base station may also receive channel information calculated by the UE based on downlink transmissions and then sent to the base station in the form of control information transmitted on an uplink control channel. Below are two figures (Dahlman and Ahmadi) showing the architecture for base station and UE downlink processing. For uplink processing, the transmit and receive chains (for the UE and base station, respectively) operate in the reverse order to that depicted in the first figure:

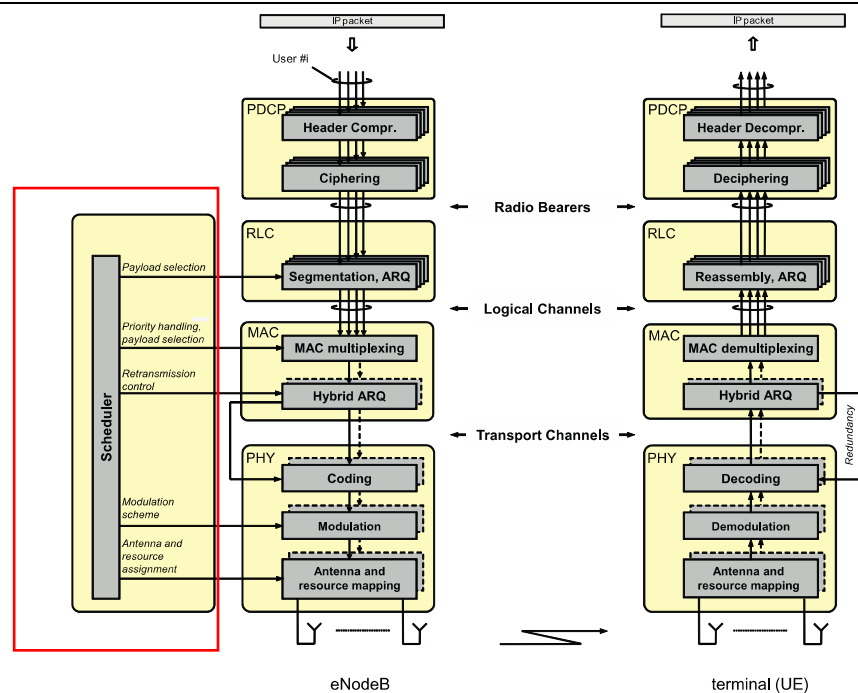


FIGURE 8.4

LTE protocol architecture (downlink).

See Dahlman 4G LTE/LTE Advanced for Mobile Broadband

As shown, the eNodeB includes processing blocks for functionality including automatic repeat request (ARQ), multiplexing, error correction coding (coding), modulation, and antenna and resource mapping. These blocks are controlled by the profile creating apparatus, or scheduler, which determines and stores parameters for each UE, and controls the processing blocks. Although the Figure depicts processing for the downlink, for each UE, the eNodeB receive processing chains are prepared and assigned in a similar way.

Similarly, signals transmitted from a 5G/NR T-Mobile base station (gNodeB) to a mobile handset or UE are done so over a DL. The gNodeB calculates signal and channel related information based on reference signals transmitted in the UL, and it

receives channel information calculated by the UE based on downlink transmissions and then sent to the eNodeB in the form of control information sent on an uplink control channel.

A figure showing the architecture for gNodeB and UE uplink and downlink processing is shown below where the gNodeB transceiver receives an uplink burst shown in the figure as a dotted line extending to the right in a purple box. As with the LTE architecture, uplink processing of the transmit and receive chains (for the UE and gNodeB, respectively) operate in the reverse order.

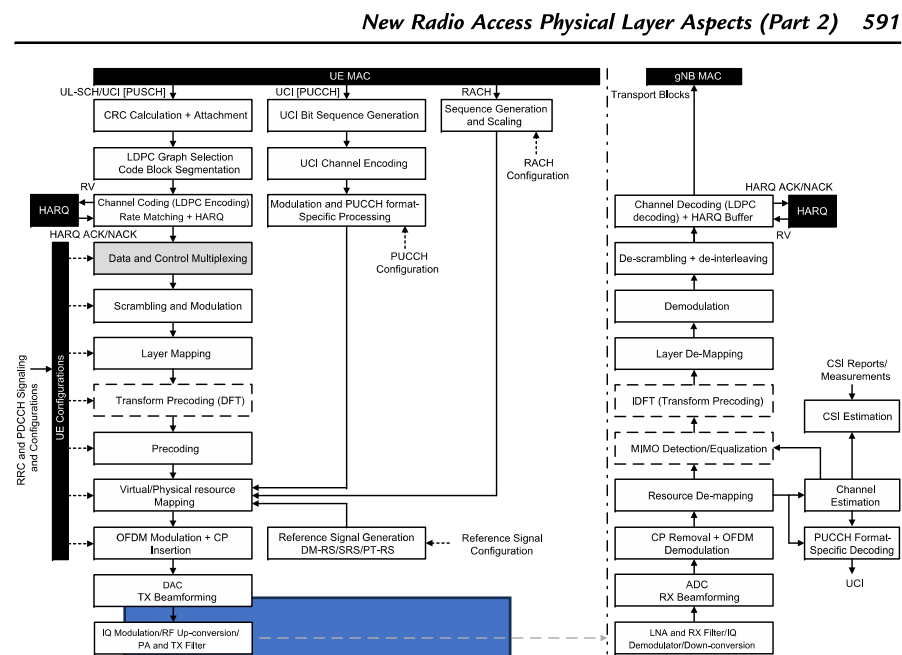


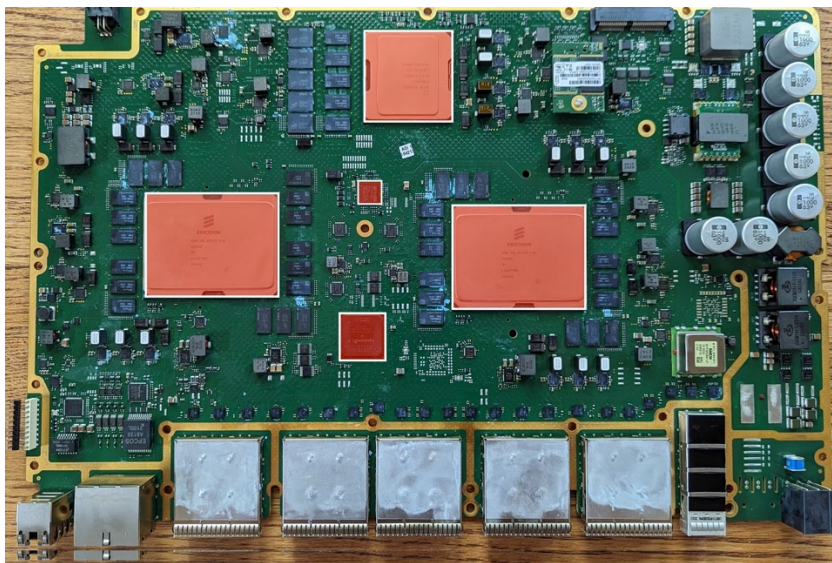
Figure 4.72
Overall uplink physical layer processing [5].

See Ahmadi 5G NR Figure 4.72 pg. 591.

The gNodeB includes processing blocks for functionality including automatic repeat request (ARQ), multiplexing, error correction coding (coding), modulation, precoding, beamforming, and antenna and resource mapping, among others. There is

an equivalent “UE Configuration” block (not shown) in the gNodeB. The profile creating apparatus that is in the gNodeB Configuration block (not shown) ultimately configures and stores profiles for each UE associated with the gNodeB. The UE Configuration block configures and stores parameters, as configured by the gNodeB radio resource controller (RRC), and also controls the processing blocks through the UE Configuration interface.

The Ericsson Baseband 6648 includes processing components to measure and determine parameters and profiles to transmit DL to and receive UL from UEs as shown in the following figure (with processing components highlighted in red for reference):



Subject to further discovery, T-Mobile uses the Ericsson Baseband 6648 units in its base stations, and those units have the following the processing units: top middle: Intel Atom Processor: P5941BC1 SRJF2 2.20 GHZ L103E581 M1T32N1700051;

	<u>small processor in center</u>: STMicroelectronics Arm Processor: STM32F103; <u>two larger rectangles in the middle</u>: Ericsson SoC: ROK 101 031/8 R2B MY L152F700 SRKH2; and <u>lower middle processing unit</u>: Altera Cyclone V FPGA: 5CGXFC5C8F23I7N F BABAU2125A. One or more of these processing units include the profile-creating apparatus of Claim 1. Similarly processing units in other T-Mobile base stations similarly include the profile-creating apparatus of Claim 1. T-Mobile's 4G and 5G base stations also include the remaining limitations of Claim 1, as discussed below.
1.1: a profile parameter determiner coupled to receive an indication of an initial burst of the first burst data signal transmitted upon the first channel to the receiving station, said profile parameter determiner for determining a value of at least one signal-related parameter and at least one channel-related parameter,	The T-Mobile base station, including the profile parameter determiner, are coupled to receive from the UE an indication of an initial burst transmission. The profile parameter determiner at the base station determines a value of at least one signal-related parameter and one-channel related parameter based on signal and channel characteristics of the communications between the base station and the UE. To the extent that T-Mobile's 4G or 5G base stations include cloud-based functionality that performs one or more of the limitations described as the profile parameter determiner, those base stations also infringe, at least under the doctrine of equivalents. The information may come in the form of control signaling information which informs the T-Mobile base station of signal-related parameters and channel-related parameters, or the UE may transmit reference signals to be measured at the base station and used to determine signal-related and channel-related parameters. Uplink signal and channel characteristics of transmissions from the UE to T-Mobile's base stations may be determined by measuring uplink signals directly (for TDD or FDD links) or may be determined by measuring transmissions from the base station to the UE and assuming channel reciprocity (for TDD links). Data signals transmitted on the first channel comprise first burst data signals. For example, and without limitation, UEs sending uplink signals to T-Mobile's 4G and 5G base stations utilize burst data signaling. <i>See, e.g.</i>, Ahmadi 5G at 256 (discussing the “bursty” nature of 5G transmissions); <i>id.</i> at 728 (noting that 5G’s “effective doubling of the uplink data rate enables shorter uplink bursts”); Dahlman 5G at 72 (“[g]iven the bursty nature of most data traffic...”); <i>id.</i> at 137 (noting that “it is beneficial to avoid placing interference-sensitive signals at the start of an uplink burst”); <i>id.</i> at Section 19.5 (discussing uplink data transmission in 5G, including scheduling of slots and mini-slot for various bursts of uplink data transmission); Dahlman 4G at 335 (noting that “[p]acket-data traffic is often highly bursty”). Communications between a base station and a UE begin with a RACH or Random Access Channel (RACH) to allow UEs to synchronize to the eNodeB and connect to the network. With LTE, UE initial access to an eNodeB is performed on the random access channel (RACH). After the transmission of the preamble during the RACH, the eNodeB transmits a DCI on the PDCCH, the DCI conveying parameters related to the transmission being scheduled, including but not limited to

frequency offsets, timing, power, MCS, and others. Once uplink resources are assigned to the UE, the UE transmits data signals to the base station from which the base station determines additional signal-related and channel-related parameters.

Uplink reference signals may be used by the eNodeB to calculate signal-related parameters as well as channel-related parameters. LTE describes two types of reference signals (see 3GPP TS 36.211v14.15.0 pg. 43), among others, to be transmitted in the uplink, which allows the eNodeB to measure signal and channel characteristics for each UE:

- Demodulation reference signals, which are associated with uplink channels PUSCH or PUCCH, and
- Sounding reference signals, which are not necessarily associated with PUSCH or PUCCH.

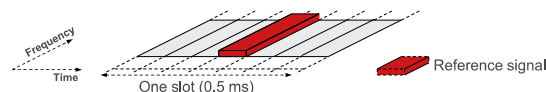
11.2 UPLINK REFERENCE SIGNALS

Similar to the downlink, reference signals are also transmitted on the LTE uplink. There are two types of reference signals defined for the LTE uplink:

- Uplink *demodulation reference signals* (DM-RS) are intended to be used by the base station for channel estimation for coherent demodulation of the uplink physical channels (PUSCH and PUCCH). Demodulation reference signals are thus only transmitted together with PUSCH or PUCCH and are then transmitted with the same bandwidth as the corresponding physical channel.
- Uplink *sounding reference signals* (SRS) are intended to be used by the base station for channel-state estimation to support uplink channel-dependent scheduling and link adaptation. The SRS can also be used in cases when uplink transmission is needed, although there is no data to transmit. One example is when uplink transmission is needed for the network to be able to control the uplink transmit timing by means of the *uplink-timing-alignment procedure* (Section 11.5). Finally, the uplink SRS can also be used to estimate the downlink channel-state assuming sufficient uplink/downlink reciprocity. This is especially of interest for TDD, where the operation of downlink and uplink on the same carrier frequency typically implies a higher degree of short-term downlink/uplink reciprocity compared to FDD.

See Dahlman – 4G LTE/LTE-Advanced for Mobile Broadband pg. 210.

LTE uplink demodulation reference signals (DM-RS) are discussed, for example, in 3GPP TS 36.211v14.15.0 clause 5.5.2. Demodulation reference signals accompany both PUSCH and PUCCH transmissions from each UE to the eNodeB. LTE DM-RS for PUSCH are discussed in 3GPP 36.211 v14.15.0 §5.5.2.1 (pg. 49), and DM-RS for PUCCH are discussed in 3GPP 36.211 v14.15.0 §5.5.2.2 (pg. 52). Uplink DM-RS are embedded in uplink transmissions as used by the eNodeB to detect and demodulate the uplink signal, as described in Dahlman. Dahlman states “in case of PUSCH transmission DM-RS is transmitted within the fourth symbol of each uplink slot⁵ (Figure 7.9).”

**FIGURE 7.9**

Transmission of uplink DM-RS within a slot in case of PUSCH transmission.

⁵The third symbol in the case of extended cyclic prefix.

The DM-RS is used for coherent detection and demodulation of the PUSCH or PUCCH. The DM-RS is used to calculate signal parameters, as well as in some instances channel parameters, associated with the uplink burst. 5G/NR DM-RS performs a similar function as LTE DM-RS as shown in 3GPP TS 38 211v16.10.0:

- Uplink DM-RS for 5G/NR PUSCH is discussed in 3GPP TS 38 211v16.10.0 clause 6.4.1.1
- Uplink DM-RS for 5G/NR PUCCH is discussed in 3GPP TS 38 211v16.10.0 clause 6.4.1.4.

Similar to LTE, 5G/NR DM-RS are used to obtain signal-related parameters for each UE, used both for uplink and downlink data and control transmissions:

“the demodulation reference signals intended for coherent demodulation of PDSCH and PUSCH are described in more detail, starting with the reference-signal structure used for OFDM. The same DM-RS structure is used for both downlink and uplink in the case of OFDM.”

Excerpt From 5G NR Erik Dahlman, Stefan Parkvall, Johan Skold. The 5G/NR uplink DM-RS is used to obtain signal related parameters (such as channel estimate) to aid in the decoding of an uplink data (PUSCH) or control (PUCCH) transmission:

“To achieve low latency, it is beneficial to locate the demodulation reference signals early in the transmission, sometimes known as front-loaded reference signals. This allows the receiver to obtain a channel estimate early and, once the channel estimate is obtained, process the received symbols on the fly without having to buffer a complete slot prior to data processing.”

Excerpt From 5G NR Erik Dahlman, Stefan Parkvall, Johan Skold. 5G/NR DM-RS may be embedded in the data or control resource block transmission as shown in Dahlman Figure 9.18:

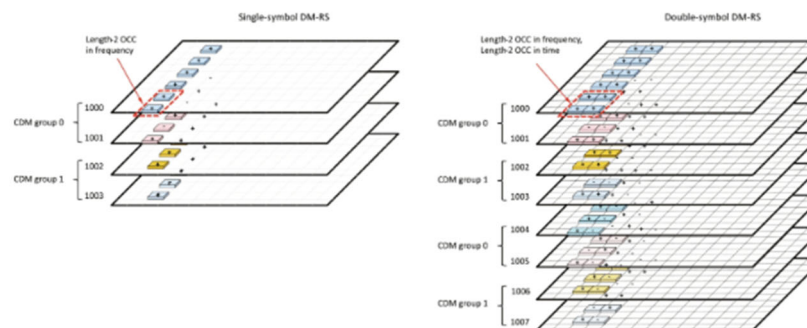


FIG. 9.18 Demodulation reference signals type 1.

Excerpt From 5G NR Erik Dahlman, Stefan Parkvall, Johan Skold.

Uplink sounding reference signals (SRS) are used to determine the channel state across the band. As described by Dahlman:

7.2.2 SOUNDING REFERENCE SIGNALS

The DM-RS discussed in [Section 7.2.1](#) are intended to be used by the base station for channel estimation to allow for coherent demodulation of uplink physical channels (PUSCH or PUCCH). A DM-RS is always transmitted together with and spanning the same frequency range as the corresponding physical channel.

In contrast, SRS are transmitted on the uplink to allow for the base station to estimate the uplink *channel state* at different frequencies. The channel-state estimates can then, for example, be used by the base-station scheduler to assign resource blocks of instantaneously good quality for uplink PUSCH transmission from the specific device (uplink channel-dependent scheduling). They can also be used to select different transmission parameters such as the instantaneous data rate and different parameters related to uplink multi-antenna transmission. The channel information obtained from the SRS can also be used for downlink transmission purposes exploiting channel reciprocity, for example downlink channel-dependent scheduling in TDD systems. As mentioned earlier, SRS transmission can also be used in other situations when uplink transmission is needed although there is no data to transmit, for example, for uplink timing estimation as part of the uplink-timing-alignment procedure. Thus, an SRS is not necessarily transmitted together with any physical channel and if transmitted together with, for example, PUSCH, the SRS may span a different, typically larger, frequency range.

See Dahlman, 4G LTE-Advanced Pro (2016) pg. 185.

As the SRS is used to determine channel state, the signal is transmitted across the band, either in one contiguous burst or in a series of frequency hopping bursts as shown in Dahlman Figure 7.15:

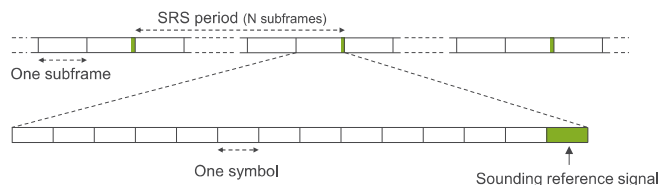


FIGURE 7.14

Transmission of SRS.

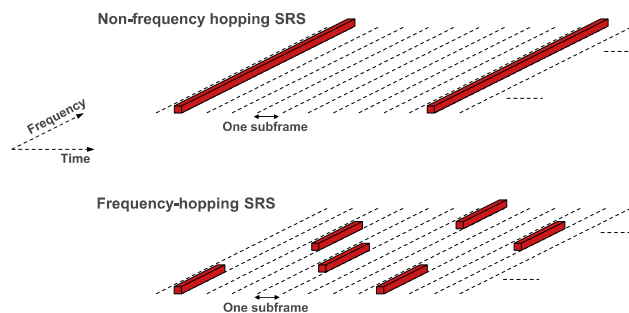


FIGURE 7.15

Nonfrequency-hopping (wideband) versus frequency-hopping SRS.

See Dahlman, 4G LTE-Advanced Pro (2016) pg. 186.

5G/NR SRS performs a similar function as LTE SRS as shown in 3GPP TS 38 211v16.10.0. Uplink SRS for 5G/NR PUSCH is discussed in 3GPP TS 38 211v16.10.0 clause 6.4.1.4.

Dahlman describes the functionality of the 5G/NR SRS:

“8.3: Uplink Channel Sounding—SRS

To enable uplink channel sounding a device can be configured for transmission of sounding reference signals (SRS). In many respects SRS can be seen as the uplink equivalence to the downlink CSI-RS in the sense that both CSI-RS and SRS are intended for channel sounding albeit in different transmission directions. Both CSI-RS and SRS can also serve as QCL references in the sense that other physical channels can be configured to be transmitted quasi-co-located with CSI-RS and SRS, respectively. Thus, given knowledge of a suitable receiver beam for the CSI-RS/SRS, the receiver knows that the same receiver beam should be suitable also for the physical channel in question.”

Excerpt From 5G NR Erik Dahlman, Stefan Parkvall, and John Skold.

As with LTE SRS, 5G/NR SRS is distinct from the DM-RS in that it is not transmitted in conjunction with DM-RS (to be used to calculate signal related parameters, as well as in some instances channel-related parameters). The LTE and 5G/NR SRS is used to measure channel related parameters, as well as in some instances signal-related parameters, to be used to assign channel dependent settings such as time/frequency allocations, transmission schemes, precoding, etc.

5G/NR SRS may be configured to span one or more OFDM symbols across a large number of subcarriers (not restricted to a reference block) as shown in Dahlman:

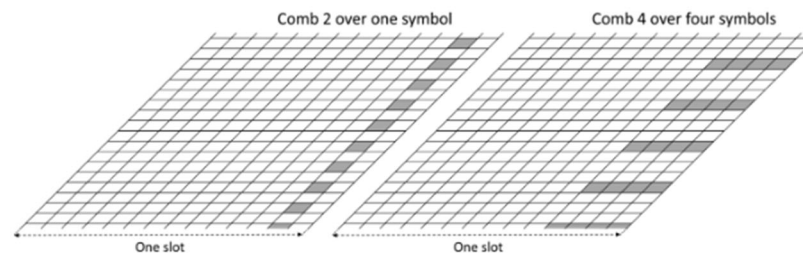
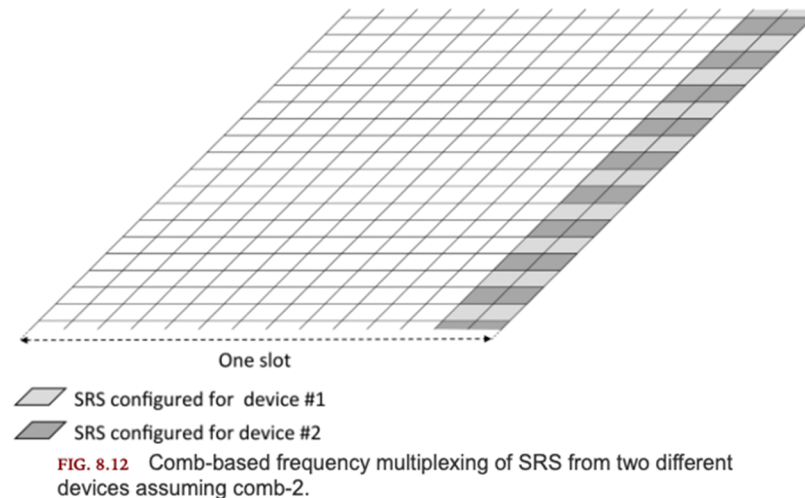


FIG. 8.11 Examples of SRS time/frequency structures.



For TDD LTE, signal-related and channel-related properties may also be measured by the UE using downlink reference signals to determine what parameters it should use. These measurements and suggested parameters for uplink allocations are communicated from the UE to the eNodeB on the control channel (PUCCH), where the eNodeB selects uplink transmit parameters and communicates those settings to the UE as part of subsequent uplink allocations.

3GPP 36.211 defines six types of downlink Reference Signals, including:

- Cell specific reference signals (CRS)
- User Equipment (UE)-specific Reference Signals (DM-RS) associated with PDSCH, EPDCCH, or MPDCCH
- Channel State Indicator Reference Signals (CSI-RS).

Section 6.10.1 of 3GPP TS 36.211 V14.15.0 (2020-09) Technical Specification states:

“The UE may assume cell-specific reference signals are, unless otherwise stated in [4, clause 12], transmitted in

- *all downlink subframes for frame structure type 1,*
- *all downlink subframes and DwPTS for frame structure type 2,*

- *non-empty subframes for frame structure type 3*

in a cell supporting PDSCH transmission.”

When using downlink reference signals to determine uplink transmit parameters, the eNodeB transmits reference signals to each UE. The UE receives these signals and uses them to estimate and predict signal and channel characteristics to the base station where the profile parameter determiner uses such information to assign resources and transmission parameters for uplink transmissions.

From the 3GPP TS 36.331 V14.16.0 (2021-01), Radio Resource Control (RRC) Protocol Specification, at Section 4.2.1 (p. 31), “The UE: - Provides channel quality and feedback information”. The base station and the UE during communications use the profile parameter determiner to determine and provide certain parameter values at the receiving station as described as follows in 3GPP TS 36.213, at Section 7.2:

The time and frequency resources that can be used by the UE to report CSI which consists of channel quality indicator (CQI), precoding matrix indicator (PMI), precoding type indicator (PTI), CSI-RS resource indicator (CRI), and/or rank indication (RI) are controlled by the eNB. For spatial multiplexing, as given in [3], the UE shall determine a RI corresponding to the number of useful transmission layers. For transmit diversity as given in [3], RI is equal to one.

CSI stands for Channel State Indicator. The CQI is a channel-related parameter, while the RI is a signal-related parameter.

See also 3GPP 36.213: Evolved Universal Terrestrial Radio Access

(E-UTRA); Physical layer procedures (Release 14), © 2021, 3GPP Organizational Partners (ARIB, ATIS, CCSA, ETSI, TTA, TTC). All rights reserved.

For example, 3GPP TS 36.331 14.16.0 (2021-01), at Section 6, “Protocol data units, formats and parameters,” (pp. 318-319), states the “UEInformationRequest is the command used by the E-UTRAN to retrieve information from the UE” and that the “UEInformationResponse message is used by the UE to transfer the information requested by the E-UTRAN.” A “UEInformationResponse” message contains parameters such as RSRP and RSRQ (see 36.331, p. 137).

The profile parameter determiner determines the value of at least one signal-related parameter, and one channel-related parameter from the data provided in the transmission from the UE to the T-Mobile base station. Such examples of signal-

	related parameters and channel-related parameters are included and described in the specification, without limitation as shown in the specification with “etc.”, to include the amount of forward error correction (FEC) of the burst, change in frequency of the burst, changes in time of the burst, changes in power levels of the burst, etc., as examples of signal-related parameters, and values of equalization weighting, antenna parameters, either at the subscriber station or at the base station, etc., as examples of channel-related parameters. ‘477 Patent 11:58-54. Other examples of more signal-related and channel-related parameters are discussed in the context of the dependent claims, and include those parameters commonly understood by a person of ordinary skill in the art. Any reference herein to signal-related parameters and channel-related parameters includes at least the aforementioned list, as well as what the person of ordinary skill in the art would understand those terms to mean.
1.2 wherein the signal-related and channel-related parameters are collectively representative of communication of the first burst data signal over the first channel to the receiving station; and	The signal-related and channel-related parameters (as discussed above) are collectively representative of communication of the first burst data signal over the first channel to the receiving station as shown in Ahmadi Figure 4.72 in the various UE blocks on the left side of the diagram and in communication with the base station.

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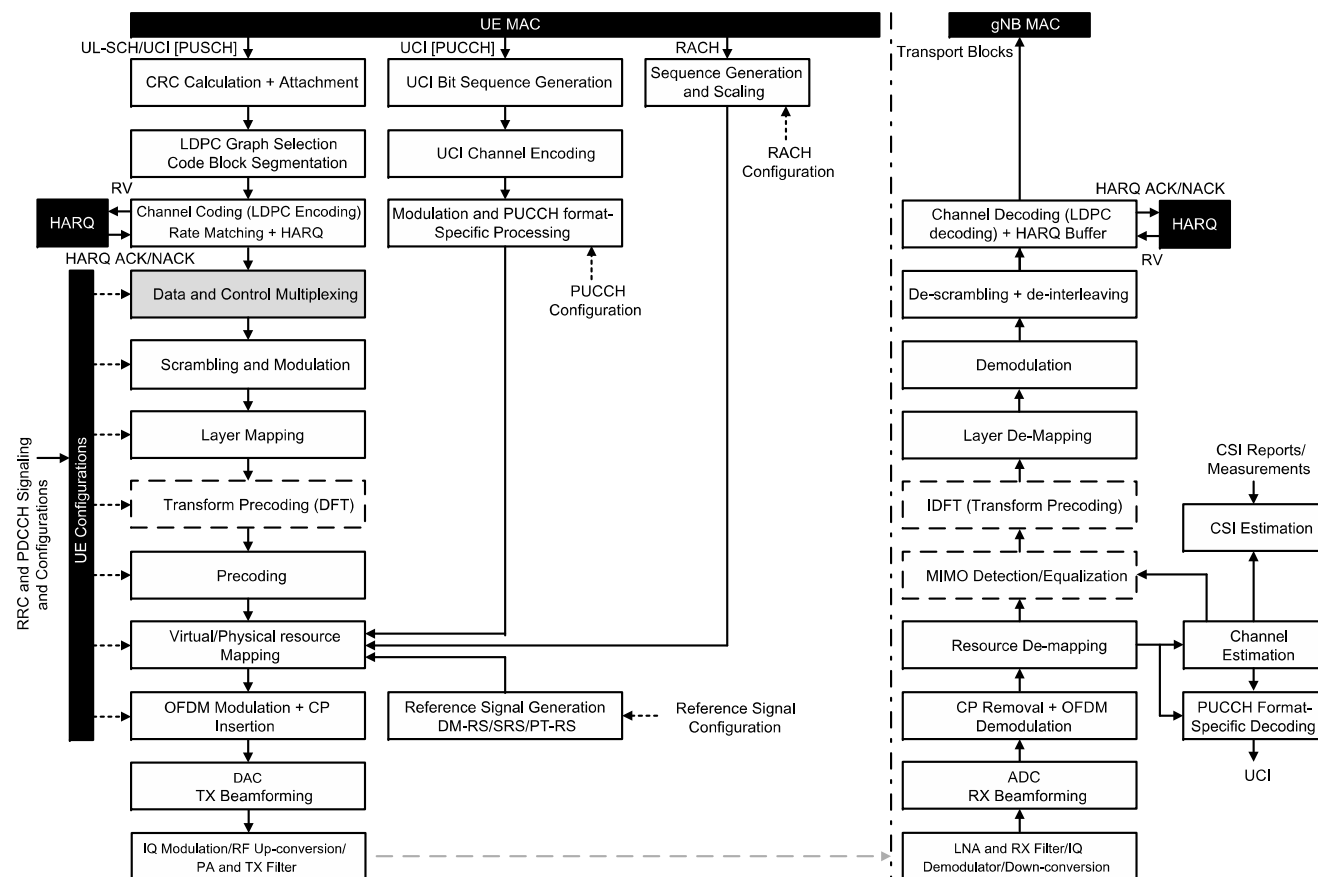


Figure 4.72
Overall uplink physical layer processing [5].

When receiving a transmission, signal and channel related parameters are calculated to aid in the demodulation and decoding of the received signal. For example, a channel estimate is performed to measure channel distortion so that an equalizer may

apply a correction to the received data or control information. In LTE and 5G/NR, these signal-related parameters may be calculated based on the DM-RS sent along with the data or control signal as described above.

LTE signal-related parameters generated from DM-RS are described in Dahlman:

7.2.1 DEMODULATION REFERENCE SIGNALS

Uplink DM-RS are intended to be used for channel estimation for coherent demodulation of the PUSCH to which the UL-SCH transport channel is mapped, as well as for the PUCCH which carries different types of uplink L1/L2 control signaling. The basic principles for uplink DM-RS are the same for PUSCH and PUCCH transmission although there are some differences—for example, in terms of the exact set of OFDM symbols in which the reference signals are transmitted. The discussion in the following primarily focuses on PUSCH DM-RM. Some additional details on the PUCCH DM-RS structure is provided in [Section 7.4](#) as part of the more general description of uplink L1/L2 control signaling.

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The DM-RS is associated with the portion of the channel used to transmit the resource blocks assigned for the data or control transmission. Dahlman also states:

In general, there is no reason to estimate the channel outside the frequency band of the corresponding PUSCH/PUCCH transmission that is to be coherently demodulated. The frequency range spanned by an uplink DM-RS is therefore equal to the instantaneous frequency range spanned by the corresponding PUSCH/PUCCH transmission. This means that, for PUSCH transmission, it should be possible to generate reference signals of different bandwidths, corresponding to the possible bandwidths of a PUSCH transmission. More specifically, it should be possible to generate reference signals of a bandwidth corresponding to $12 \cdot N$ sub carriers, where N corresponds to the bandwidth of the PUSCH transmission measured in number of resource blocks.⁶

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For LTE, the network (eNodeB) selects the precoder for precoder-based multi-antenna uplink transmission (using the SRS), as described by Dahlman-LTE-A:

In order to select a suitable precoder, the network needs information about the uplink channel. Such information can, for example, be based on measurements on the uplink sounding reference signals (Section 11.2.2). As indicated in [Figure 11.20](#), sounding reference signals (SRS) are transmitted non-precoded – that is, directly on the different antenna ports. The received SRS thus reflect the channel of each antenna port, not including any precoding. Based on the received SRS, the network can thus decide on a suitable uplink transmission rank and corresponding uplink precoder matrix and provide information about the selected rank and precoder matrix as part of the scheduling grant.

See Dahlman LTE-Advanced page 224

For 5G/NR, the DM-RS are used in a similar manner to LTE:

“The NR reference signals include:

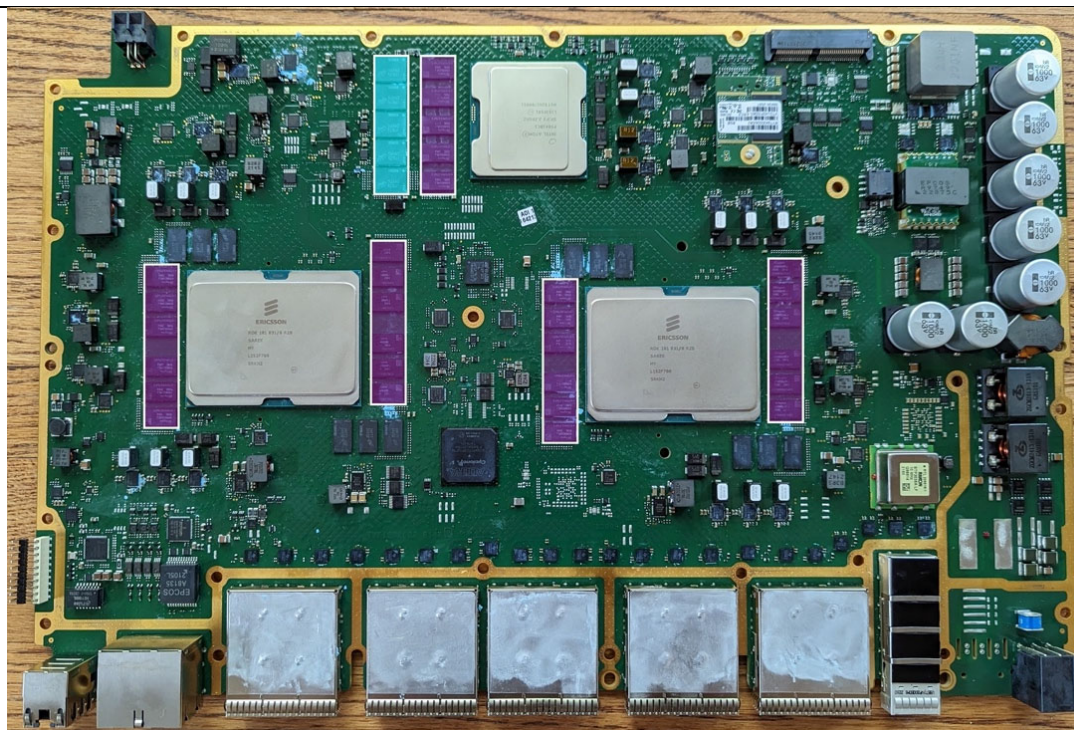
- *Demodulation reference signals (DM-RS) for PDSCH are intended for channel estimation at the device as part of coherent demodulation. They are present only in the resource blocks used for PDSCH transmission. Similarly, the DM-RS for PUSCH allows the gNB to coherently demodulate the PUSCH.”*

Excerpt From 5G NR Erik Dahlman, Stefan Parkvall, Johan Skold.

LTE sounding reference signals (SRS) are used to estimate channel-related parameters as described in Dahlman:

	7.2.2 SOUNDING REFERENCE SIGNALS The DM-RS discussed in Section 7.2.1 are intended to be used by the base station for channel estimation to allow for coherent demodulation of uplink physical channels (PUSCH or PUCCH). A DM-RS is always transmitted together with and spanning the same frequency range as the corresponding physical channel. In contrast, SRS are transmitted on the uplink to allow for the base station to estimate the uplink <i>channel state</i> at different frequencies. The channel-state estimates can then, for example, be used by the base-station scheduler to assign resource blocks of instantaneously good quality for uplink PUSCH transmission from the specific device (uplink channel-dependent scheduling). They can also be used to select different transmission parameters such as the instantaneous data rate and different parameters related to uplink multi-antenna transmission. The channel information obtained from the SRS can also be used for downlink transmission purposes exploiting channel reciprocity, for example downlink channel-dependent scheduling in TDD systems. As mentioned earlier, SRS transmission can also be used in other situations when uplink transmission is needed although there is no data to transmit, for example, for uplink timing estimation as part of the uplink-timing-alignment procedure. Thus, an SRS is not necessarily transmitted together with any physical channel and if transmitted together with, for example, PUSCH, the SRS may span a different, typically larger, frequency range. As described above, 5G/NR SRS perform a similar role as the SRS used in LTE.
1.3 a profile parameter storage device coupled to said profile parameter determiner, said profile parameter storage device for storing values representative of the at least one	The determined signal-related and channel-related values are stored in a profile parameter storage device (coupled to the profile parameter determiner) within the receiving station, where they are used to improve transmission and reception between the base station and the UE. To the extent that T-Mobile's 4G or 5G base stations include cloud-based functionality that perform one or more of the limitations described here such as a profile parameter storage device, those base stations also infringe, at least under the doctrine of equivalents. Shown below in teal is a Micron D9XPG, and in purple a SKynixH5AN8G6NCJ 8G DDR4 Micron D9XPG 2G DDR4. These are both examples of memory modules that the Baseband unit may use to store the profiles within a T-Mobile 4G and 5G base station. Additional memory modules, all of which are coupled to the profile parameter determiner, may also store profile related information.

signal-related parameter and the at least one channel-related parameter determined by said profile parameter determiner,



For both the downlink and the uplink, the processing blocks must be configured to encode or decode the radio signals transmitted and received by the eNodeB. In the case of the LTE eNodeB, the profile parameter storage device coupled to said profile parameter determiner is shown in Dahlman Figure 8.4 as the “Scheduler” block, where the block stores values representative of the at least one signal-related parameter and the at least one channel-related parameter determined by said profile parameter determiner. An example, without limitation, of a signal-related parameter is the modulation scheme, and an example, without limitation, of a channel-related parameter is the physical resource assignment, where the modulation scheme is related to signal characteristics, and the resource assignment is related to channel characteristics. In the case of the 5G/NR gNodeB, the profile parameter storage device coupled to said profile parameter determiner is shown in Ahmadi Figure 4.72 as the “UE Configurations” block, where the block stores values representative of the at least one signal-related parameter and the at least one channel-related parameter determined by said profile parameter determiner.

Additional examples of signal and channel related parameters are discussed elsewhere in these contentions.

1.3 the values stored at said profile parameter storage device to be used to facilitate receive operations performed at the receiving station on subsequent bursts of the first burst data signal.

The eNodeB calculates and stores time/frequency resource blocks, modulation and coding schemes, antenna mapping, precoding schemes, and other signal-related and channel-related parameters in the block labeled “Scheduler” in Dahlman. When allocating the next uplink for each UE, the eNodeB retrieves these parameters and includes them in the uplink allocation. When the UE transmits the uplink burst using the parameters prescribed by the eNodeB, the stored parameters are fed to the various signal processing blocks as shown in Dahlman Figure 8.4 as shown:

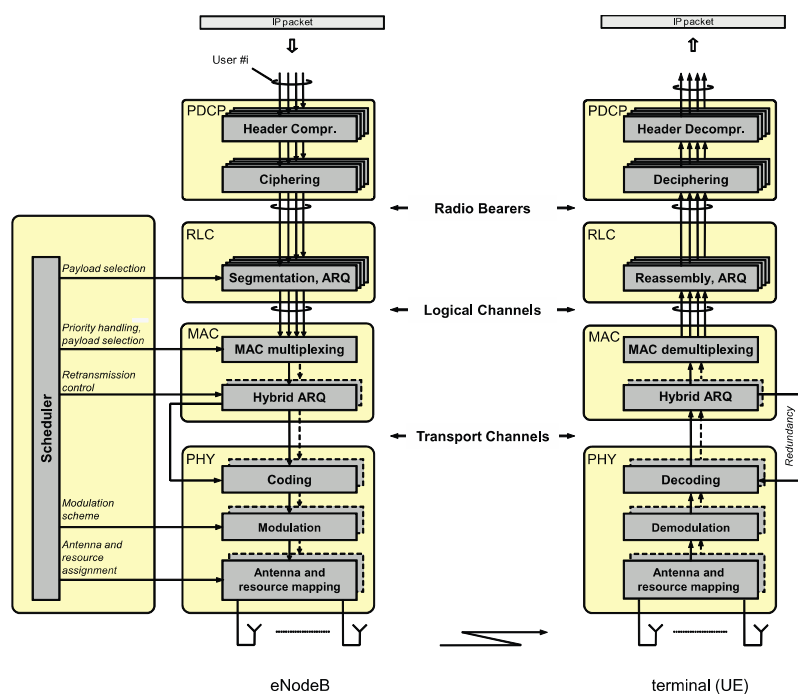


FIGURE 8.4

LTE protocol architecture (downlink).

See Dahlman 4G LTE/LTE Advanced for Mobile Broadband

	Similarly, for 5G/NR, the gNodeB calculates and stores time/frequency resource blocks, modulation and coding schemes, antenna mapping, precoding schemes, and other signal-related and channel-related parameters as shown in the block labelled “UE Configuration” in Ahmadi. When allocating the next uplink for each UE, the gNodeB retrieves these parameters and includes them in the uplink allocation. When the UE transmits the uplink burst using the parameters prescribed by the gNodeB, the stored parameters are fed to the various signal processing blocks as shown in Ahmadi Figure 4.72. See Ahmadi 5G NR Figure 4.72 pg. 591.
2. The apparatus of claim 1 wherein the receiving station is operable in a communication system in which communication protocols include a contention period and wherein the initial burst of the first burst data signal, responsive to which said profile parameter determiner determines the at least one parameter, is communicated during the contention period.	See disclosure for Claim 1. In addition, the receiving station in T-Mobile 4G and 5G base stations include a receiving station operable in a communication system in which the protocols include a contention period in the uplink transmission where access is given for the UEs to communicate data burst of uplink data. Further, the initial burst of the first burst data signal communicated during the contention period is responsive to which the profile parameter determiner determines at least one parameter. 3GPP defines the Random Access Channel (RACH) to allow UEs to synchronize to the eNodeB and connect to the network. With LTE, UE initial access to an eNodeB is performed on the RACH. Each UE randomly selects a preamble sequence from a set of orthogonal sequences available for the eNodeB cell. The UE transmits the selected preamble sequence on the RACH, and the eNodeB uses the signal to detect the UE and estimate transmission correction parameters including timing and power for the UE. The eNodeB then assigns resources to the UE via the PDCCH (physical downlink control channel) and transmits a response to the UE on the DL-SCH (downlink shared channel). This response includes the resource allocation for the UE as well as uplink timing and transmit power adjustments for the UE based on the measurement performed above. This timing measurement and adjustment process is performed for each UE as each requires a timing offset and transmit power adjustment unique to its location relative to the eNodeB, and it takes place over the RACH during a contention period. The eNodeB defines the resource blocks to be used for RACH and periodically broadcasts those parameters on the broadcast channel. This is how a new UE learns the pool of available random preambles to choose from and how it knows when to transmit the RACH signal. 3GPP 36.331 describes the RACH parameters and the RACH configuration broadcast by the eNodeB. See 3GPP TS 36.331 14.16.0 pg. 427 for the RACH-ConfigCommon information element and pg. 428 for the RACH-ConfigCommon field descriptions. The Random Access procedure is described in 3GPP TS 36.321 version 14.13.0 §5.1. Processing (by the UE) of a Random Access Response is described in 3GPP TS 36.321 version 14.13.0 §5.1.4, including the following clause describing the determined parameters sent by the eNodeB:

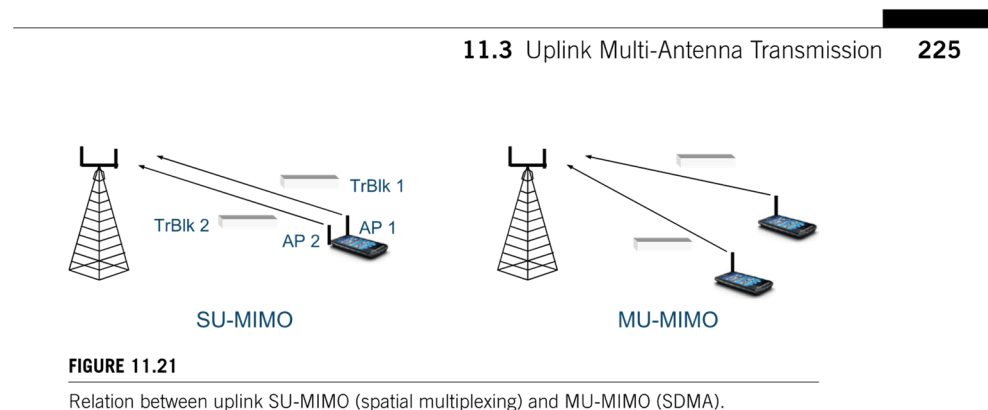
	- if the Random Access Response contains a Random Access Preamble identifier corresponding to the transmitted Random Access Preamble (see clause 5.1.3), the MAC entity shall: - consider this Random Access Response reception successful and apply the following actions for the serving cell where the Random Access Preamble was transmitted: - process the received Timing Advance Command (see clause 5.2); - indicate the <i>preambleInitialReceivedTargetPower</i> and the amount of power ramping applied to the latest preamble transmission to lower layers (i.e., (PREAMBLE_TRANSMISSION_COUNTER – 1) * <i>powerRampingStep</i>); - if the SCell is configured with <i>ul-Configuration-r14</i>, ignore the received UL grant otherwise process the received UL grant value and indicate it to the lower layers; - if, except for NB-IoT, <i>ra-PreambleIndex</i> was explicitly signalled and it was not 000000 (i.e., not selected by MAC): - consider the Random Access procedure successfully completed. - else if, the UE is an NB-IoT UE, <i>ra-PreambleIndex</i> was explicitly signalled and it was not 000000 (i.e., not selected by MAC) and <i>ra-CFRA-Config</i> is configured: - consider the Random Access procedure successfully completed. - the UL grant provided in the Random Access Response message is valid only for the configured carrier (i.e. UL carrier used prior to this Random Access procedure). The base station and the eNodeB has determined, for example as described above a timing advance and transmit power setting for the UE (but other examples such as MCS and other parameters referenced in these contentions can be determined as well), to use for subsequent transmissions in a receiving station operable in a communication system in which communication protocols include a contention period and wherein the initial burst of the first burst data signal takes place during the contention period.
3. The apparatus of claim 1 wherein the channel-related parameter is representative of a	See disclosure for Claim 1. In addition, the channel-related parameter is representative of a channel condition of the first channel, in that the uplink SRS measurements provide the eNodeB with information on the channel conditions for each UE.

channel condition of the first channel.	• Uplink SRS are intended to be used by the base station for channel-state estimation to support uplink channel-dependent scheduling and link adaptation. The SRS can also be used in other cases when uplink transmission is needed although there is no data to transmit. One example is when uplink transmission is needed for the network to be able to estimate the uplink receive timing as part of the <i>uplink-timing-alignment procedure</i>, see Section 7.6. See Dahlman, 4G LTE-Advanced Pro (2016) pg. 177. For 5G/NR, the SRS performs a similar function as LTE. “8.3: Uplink Channel Sounding—SRS <i>To enable uplink channel sounding a device can be configured for transmission of sounding reference signals (SRS). In many respects SRS can be seen as the uplink equivalence to the downlink CSI-RS in the sense that both CSI-RS and SRS are intended for channel sounding albeit in different transmission directions. Both CSI-RS and SRS can also serve as QCL references in the sense that other physical channels can be configured to be transmitted quasi-co-located with CSI-RS and SRS, respectively. Thus, given knowledge of a suitable receiver beam for the CSI-RS/SRS, the receiver knows that the same receiver beam should be suitable also for the physical channel in question.”</i> Excerpt From 5G NR Erik Dahlman, Stefan Parkvall, Johan Skold.
4. The apparatus of claim 3 wherein the channel-related parameter determined by said profile parameter determiner comprises a value representative of fading exhibited	See disclosure for Claim 3. In addition, the channel-related parameter determined by the profile parameter determiner does comprise a value representative of fading exhibited in the first channel. Channel fading is when parts, or all of the channel between the UE and the eNodeB are weak, which can arise because of destructive interference, an obstacle moving into the path between the devices, or even rain. Across the frequency spectrum of one OFDM symbol, there are DM-RS signals which are used to measure the channel at that subcarrier. For the data resource blocks between the DM-RS signals, measurements can be interpolated between two DM-RS signals, and over time measurements of DM-RS signals can be interpolated over multiple OFDM symbols. Measurements based on the SRS may also be used to improve the channel estimate and channel correction to compensate for fading. See Ahmadi 5G NR Figure 4.72 (above) and channel estimate/equalization blocks.

upon the first channel.	
5. The apparatus of claim 4 wherein the receiving station comprises an equalizer for performing equalization operations when the at least the first burst data signal and wherein the value representative of fading exhibited when the first channel comprises an equalizer weighting value to be used by the equalizer during the equalization operations.	See disclosure for Claim 4. In addition, the T-Mobile receiving station includes equalizers for equalizing the first burst data signal, wherein the value representative of fading exhibited when the first channel comprises an equalizer weighting value to be used by the equalizer during the equalization operations. For example, and without limitation, each of the demodulators in T-Mobile's 4G and 5G base stations include an equalizer for equalizing data signals applied to that demodulator. Ahmadi 5G NR, Figure 4.72 depicts a 5G receive chain with an equalization step performed by the demodulator. As shown, a channel estimator receives the resource de-mapped signals, performs channel estimation, and passes the channel estimate on to the equalization block for equalization before layer de-mapping, demodulation, channel decoding, and other processing. <i>See also id.</i> at Chapter 3 (discussing the equalization applied by the receiver's demodulators); <i>See also id.</i> at Figure 3.15 (showing different aspects of equalization in 5G). T-Mobile's 4G base stations require an equalizer for each incoming transmission. For example, and without limitation, in the case DFTS-OFDM, Dahlman explains the need for equalization at Dahlman 4G LTE/LTE Advanced for Mobile Broadband, at 54-55. <i>See also id.</i> at 52; <i>See also id.</i> at 26, 49-55 (discussing various scenarios in which equalization is utilized in 4G). As shown and discussed by Dahlman, equalization is performed on uplink transmissions as part of the demodulation process in 4G LTE. With regard to the first channel comprises an equalizer weighting value, T-Mobile's base stations maintain filter weight profiles associated with equalization and/or antenna weights for each UE. <i>See, e.g.,</i> Dahlman 4G at Chapter 4 (discussing the equalization filter weight values maintained and stored for each UE utilizing 4G LTE); <i>id.</i> at Chapter 5 (discussing multi-antenna techniques utilized in 4G, and the antenna filter weight values maintained and stored for each UE). <i>See also</i> Ahmadi, 5G NR at Chapter 3 (discussing the equalization filter weight values maintained and stored for each UE utilizing 5G); <i>id.</i> at Chapter 4 (discussing the extensive use of multi-antenna technologies in 5G, and the antenna filter weight values maintained and stored for each UE). <i>See also id.</i> at 411 ("Massive MIMO is one of the main enabling technologies in 5G wireless communications."); <i>id.</i> at 515 (discussing some of the ways that beamforming weights are determined); <i>id.</i> at Section 4.1.9 (discussing Downlink MIMO options in 5G, including the various forms of beamforming used in 5G and the associated beamforming antenna filter weight values maintained and stored for each UE). <i>See also</i>, Dahlman 5G at 247, 256-57 (discussing antenna weights and noting that "in contrast to the downlink, where the network may or may not use the precoder matrix indicated by the PMI, in the uplink direction the device is assumed to use the precoder provided by the network"); <i>id.</i> at Section 8.1.8 discussing "spatial filters" which comprise filter weight portions as described in this claim).

6. The apparatus of claim 3 wherein the receiving station comprises an antenna assembly and wherein the channel-related parameter determined by said profile parameter determiner comprises an antenna parameter related to the antenna assembly.

See disclosure for Claim 3. In addition, the T-Mobile 4G and 5G base stations include a receiving station with an antenna assembly and the profile parameter determiner determines in the profile an antenna parameter related to the antenna assembly. LTE employs several forms of multi-antenna communication including SU-MIMO, MU-MIMO, beamforming, and spatial multiplexing. An LTE or 5G/NR eNodeB may receive spatially multiplexed transmissions from multiple UEs simultaneously (MU-MIMO in the following figure) or from individual UEs transmitting on separate resource blocks (SU-MIMO in the following figure).



Dahlman Figure 11.12

Uplink multi-antenna transmission was first supported in LTE with Release 10:

7.3 UPLINK MULTI-ANTENNA TRANSMISSION

Downlink multi-antenna transmission was supported by the LTE specification from its first release (release 8). With LTE release 10, support for uplink multi-antenna transmission—that is, uplink transmission relying on multiple transmit antennas at the device side—was also introduced for LTE. Uplink multi-antenna transmission can be used to improve the uplink link performance in different ways:

- to improve the achievable data rates and spectral efficiency for uplink data transmission by allowing for antenna precoding supporting uplink beam-forming as well as spatial multiplexing with up to four layers for the uplink physical data channel PUSCH;
- to improve the uplink control-channel performance by allowing for transmit diversity for the PUCCH.

Dahlman 4G, LTE-Advance Pro and The Road to 5G, pg. 189.

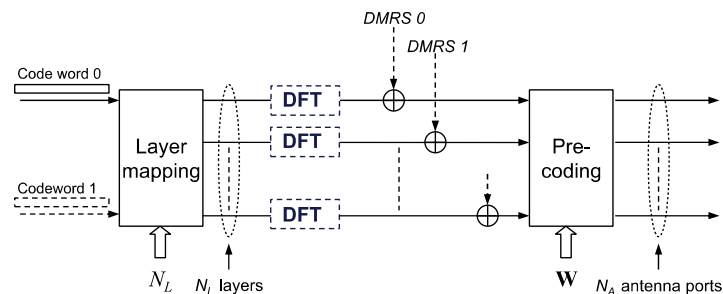
Antenna precoding is a technique used to maximize the UE's signal strength at the eNodeB while reducing interference to other receivers. See Dahlman §7.3.1:

7.3.1 PRECODER-BASED MULTI-ANTENNA TRANSMISSION FOR PUSCH

As illustrated in [Figure 7.18](#), the structure of the uplink antenna precoding is very similar to that of downlink antenna precoding (Section 6.3), including the presence of precoded DM-RS (one per layer) similar to downlink non-codebook-based precoding (Figure 6.18). Uplink

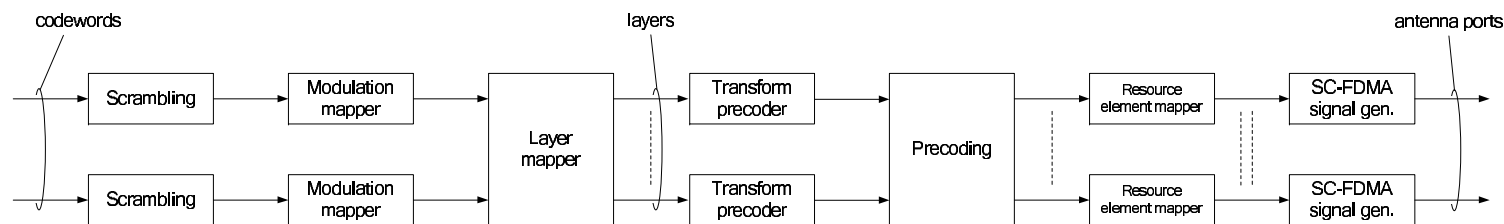
antenna precoding supports transmission using up to four antenna ports, allowing for spatial multiplexing with up to four layers.

UE processing for precoder-based multi-antenna transmission is shown in Dahlman Figure 7.18:

**FIGURE 7.18**

Precoder-based multi-antenna transmission for LTE uplink.

As shown in the above figure, data streams are mapped to layers, then precoding to the layers. The output of the precoder is routed to the antenna ports. On the eNodeB receiver, the same process is applied in reverse: the precoder is applied to the receive antenna ports, and the codewords are extracted by a layer mapper. A similar example of the transmission processing for a UE transmitting two layers is shown in 3GPP 36.211 Figure 5.3-1:

**Figure 5.3-1: Overview of uplink physical channel processing**

Multi-antenna reception involves combining received signals from two or more antennas, often with “weights” applied to each antenna transducer to enhance the signal from specific antennas, frequencies, or spatial directions. Weights can also be used to reduce the magnitude of signals from unwanted interferers. An example of block diagram of a multi-antenna T-Mobile base station receiver with applied weights to isolate individual transmissions is shown below:

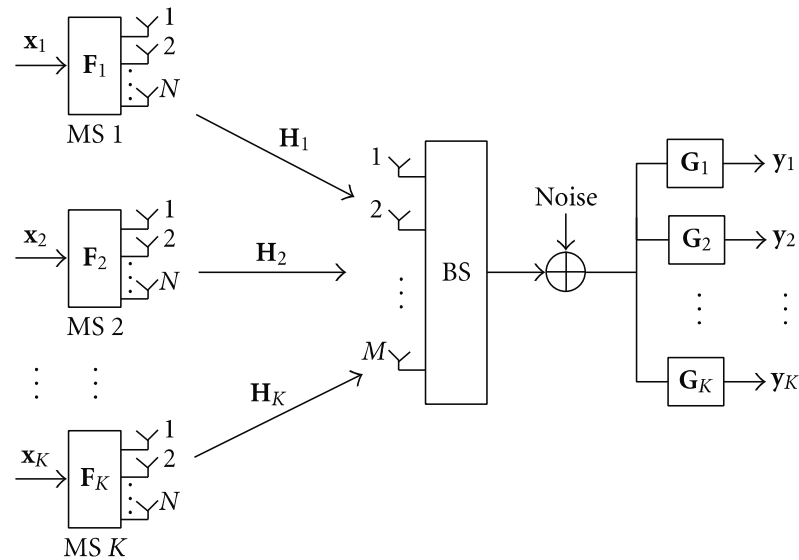


FIGURE 1: Block diagram of an uplink multiuser MIMO wireless system with an M -antenna BS and K mobile users each with N antennas.

See Hu, Yang: “*Combined Transceiver Optimization for Uplink Multiuser MIMO with Limited CSI*”, ISRN Signal Processing Volume 2011, Article ID 735695

Precoding is one example of a channel-related parameter determined by said profile parameter determiner which comprises an antenna parameter related to the antenna assembly. For codebook-based precoding, the precoding matrix is selected based on the number of streams to transmit and the number of antenna ports, as shown in Dahlman:

	In order to select a suitable precoder, the network needs information about the uplink channel. Such information can, for example, be based on measurements on the uplink SRS
--	---

Table 7.2 Subset of Uplink Precoder Matrices for Four Antenna Ports and Different Transmission Ranks					
Transmission Rank	Codebook Index				
	0	1	2	3	...
1	$\frac{1}{2} \begin{bmatrix} 1 \\ 1 \\ 1 \\ -1 \end{bmatrix}$	$\frac{1}{2} \begin{bmatrix} 1 \\ 1 \\ j \\ j \end{bmatrix}$	$\frac{1}{2} \begin{bmatrix} 1 \\ 1 \\ -1 \\ 1 \end{bmatrix}$	$\frac{1}{2} \begin{bmatrix} 1 \\ 1 \\ -j \\ -j \end{bmatrix}$	...
2	$\frac{1}{2} \begin{bmatrix} 1 & 0 \\ 1 & 0 \\ 0 & 1 \\ 0 & -j \end{bmatrix}$	$\frac{1}{2} \begin{bmatrix} 1 & 0 \\ 1 & 0 \\ 0 & 1 \\ 0 & j \end{bmatrix}$	$\frac{1}{2} \begin{bmatrix} 1 & 0 \\ -j & 0 \\ 0 & 1 \\ 0 & 1 \end{bmatrix}$	$\frac{1}{2} \begin{bmatrix} 1 & 0 \\ -j & 0 \\ 0 & 1 \\ 0 & -1 \end{bmatrix}$	...
3	$\frac{1}{2} \begin{bmatrix} 1 & 0 & 0 \\ 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix}$	$\frac{1}{2} \begin{bmatrix} 1 & 0 & 0 \\ -1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix}$	$\frac{1}{2} \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 1 & 0 & 0 \\ 0 & 0 & 1 \end{bmatrix}$	$\frac{1}{2} \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ -1 & 0 & 0 \\ 0 & 0 & 1 \end{bmatrix}$	...
4	$\frac{1}{2} \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$	—	—	—	...

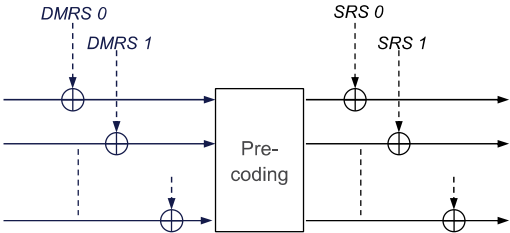


FIGURE 7.20
Illustration of SRS transmitted *after* uplink antenna precoding.

(Section 7.2.2). As indicated in Figure 7.20 SRS are transmitted non-precoded—that is, directly on the different antenna ports. The received SRS thus reflect the channel of each antenna port, not including any precoding. Based on the received SRS, the network can thus decide on a suitable uplink transmission rank and corresponding uplink precoder matrix, and provide information about the selected rank and precoder matrix as part of the scheduling grant.

The previous paragraph assumed the same number of antenna ports for PUSCH as for SRS. This is a relevant situation and the SRS is, in this case, used to aid the selection of the precoding matrix, as discussed in the preceding paragraphs. However, there are also situations when SRS and PUSCH use *different* numbers of antenna ports. One example is uplink transmission of two layers (two antenna ports), where the eNodeB would like to use SRS to probe the channel for potential four-layer transmission. In this case the SRS is transmitted on a *different* set of antenna ports than the PUSCH to aid the eNodeB in assessing the benefits, if any, of switching to four-layer transmission.

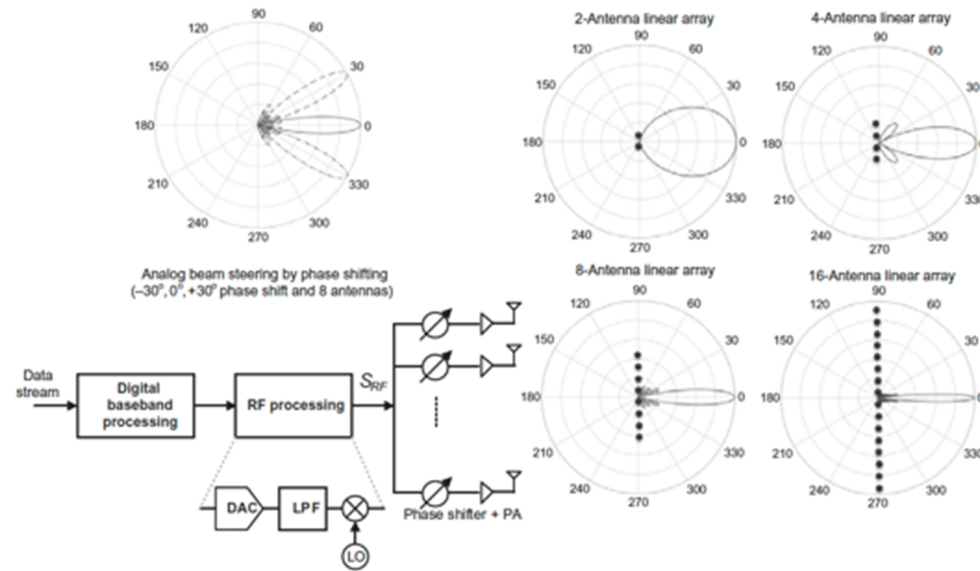
Dahlman 4G Advanced Pro pp 191-193.

The T-Mobile base stations also include antennas which are used in antenna combining techniques such as beamforming (including both transmit and receive beamforming) and MIMO. *See, e.g.*, Dahlman 5G NR at Section 5.1.9 (discussing the “beam-centric design” of 5G, and noting that “[s]upport for (a large number of) steerable antenna elements for both transmission and reception is a key feature of NR”).

See also, Ahmadi 5G NR at Section 4.1.9.3 (Discussing Analog, Digital, and Hybrid Beamforming in 5G). *Id.* at 564:

Large antenna arrays and beamforming play an important role in 5G implementations since both base stations and devices can accommodate a larger number of antenna elements at mmWave frequencies. Aside from a higher directional gain, these antenna types offer complex beamforming capabilities. This allows increasing the capacity of cellular networks by improving the signal-to-interference ratio through direct targeting of user groups. The narrow transmit-beams simultaneously lower the amount of interference in the radio propagation environment and make it possible to maintain sufficient signal power at the receiver terminal at larger distances in rural areas. An important prerequisite for any beamforming architecture is a phase coherent signal, which means that there is a defined and stable phase relationship between all RF carriers. A fixed phase offset between the carriers can be used to steer the main antenna lobe to a desired direction. A major difference between NR and LTE is the support for beamformed control channels, which resulted in different reference signal design for each control channel. The NR physical channels and signals, including those used for control and synchronization, have all been designed to support beamforming. The CSI for operation with a large number of antennas can be obtained via CSI reports from the devices based on transmission of CSI-RSs in the downlink, as well as using uplink measurements exploiting channel reciprocity.

Id. at 565 (depicting some basic analog beamforming techniques):



Id. at 566 (discussing digital beamforming techniques):

While analog beamforming is generally restricted to one RF chain even when using large number of antenna arrays, digital beamforming in theory supports as many RF chains as there are antenna elements. If suitable precoding is performed in the digital-domain baseband, this would yield higher flexibility regarding the transmission and reception. The additional degree of freedom can be leveraged to perform advanced techniques such as multi-beam MIMO. These advantages result in the highest theoretical performance possible compared to other beamforming architectures. Fig. 4.64 illustrates the high-level digital beamforming transmitter architecture. Uneven beam is a problem

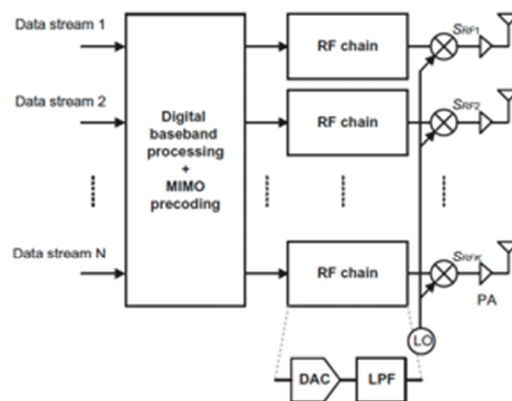


Figure 4.64
Digital beamforming transmitter architecture.

Id. at 567 (noting the use of beamforming in both transmit and receive processing in 5G):

Multiple antennas at the transmitter and receiver can be used to achieve array and diversity gain instead of capacity gain. In this case, the same symbol weighted by a complex-valued scale factor is sent from each transmit antenna, so that the input covariance matrix has unit rank. This scheme is referred to as beamforming. It must be noted that there are two conceptually and practically different classes of beamforming: (1) direction-of-arrival beamforming (i.e., adjustment of transmit or receive antenna directivity) and (2) eigen-beamforming (i.e., a mathematical approach to maximize signal power at the receive antenna based on certain criterion). In this section, we only consider eigen-beamforming schemes.

Id. at 572 (depicting hybrid beamforming):

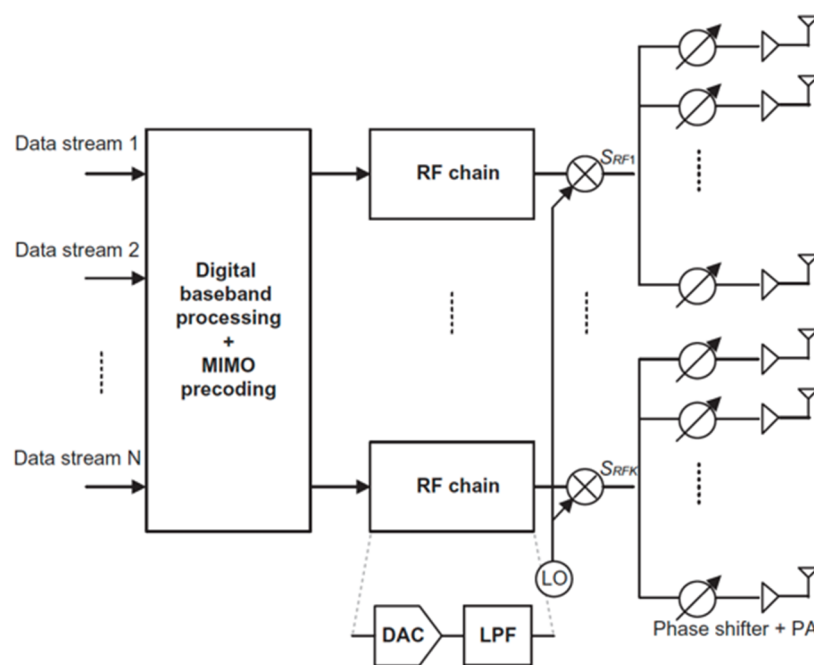


Figure 4.66
Hybrid beamforming architecture.

See also *id.* at Section 4.1.9.4 (Discussing “full-dimension MIMO”). *Id.* at 574 (depicting various types of beamforming):

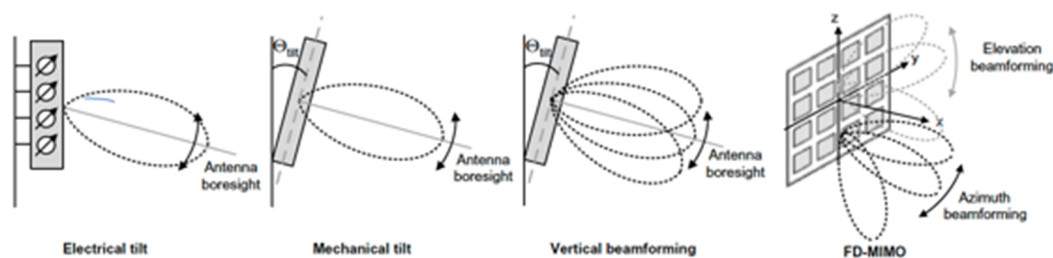


Figure 4.67

Illustration of mechanical/electrical tilting, vertical, and 3D beamforming [23].

See also Dahlman 4G at Section 5.5.3 (discussing nonlinear receiver processing in 4G); *id.* at Section 11.3 (discussing “uplink multi-antenna transmission” including SU-MIMO, MU-MIMO, and beamforming uplink transmissions in 4G). *Id.* at Figure 11.21 (showing uplink SU-MIMO and MU-MIMO in LTE):

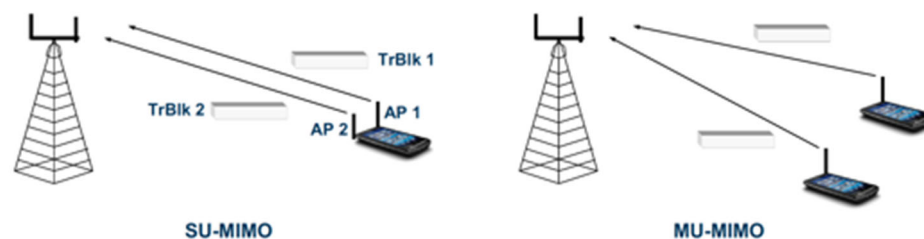
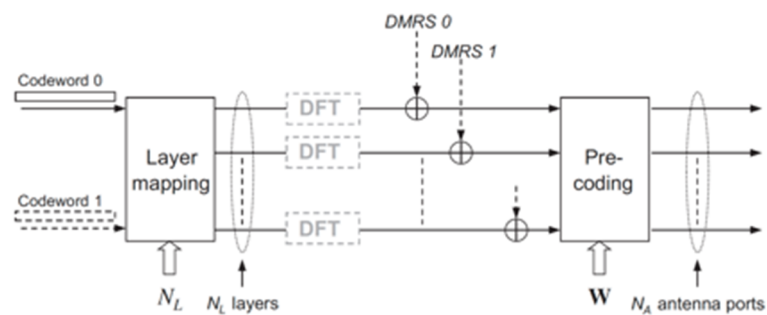


FIGURE 11.21

SU-MIMO and MU-MIMO

Id. at Figure 11.18 (depicting UE processing for precoder-based multi-antenna uplink transmissions in LTE):

**FIGURE 11.18**

Precoder-based multi-antenna transmission for LTE uplink

A similar example of the transmission processing for a UE transmitting two layers is shown in 3GPP 36.211 Figure 5.3-1:

**Figure 5.3-1: Overview of uplink physical channel processing**

An example of a block diagram of a multi-antenna base station receiver with applied weights to isolate individual transmissions is shown below:

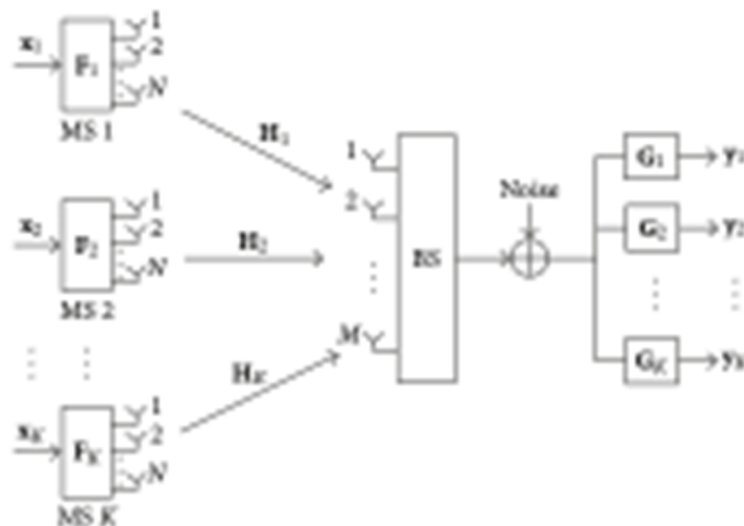


FIGURE 1: Block diagram of an uplink multiuser MIMO wireless system with an M -antenna BS and K mobile users each with N antennas.

Hu, Yang: "Combined Transceiver Optimization for Uplink Multiuser MIMO with Limited CSI", ISRN Signal Processing Volume 2011, Article ID 735695.

7. The apparatus of claim 3 wherein the first burst data signal is transmitted by a first sending station having an antenna assembly and wherein the channel-related

See disclosure for Claim 3. In addition, the T-Mobile 4G and 5G base stations communicate with a first sending station, or UE with an antenna assembly, wherein the first burst data signal is transmitted by a sending station with an antenna assembly and the profile parameter determiner determines in the profile an antenna parameter related to the antenna assembly. Specifically, for precoder based uplink multi-antenna transmissions, the precoding matrix is chosen based on channel measurements such as those provided by the sounding reference symbol (SRS). Dahlman describes the technique used for LTE:

parameter determined by said profile parameter determiner comprises an antenna parameter related to the antenna assembly.

In order to select a suitable precoder, the network needs information about the uplink channel. Such information can, for example, be based on measurements on the uplink SRS

Table 7.2 Subset of Uplink Precoder Matrices for Four Antenna Ports and Different Transmission Ranks

Transmission Rank	Codebook Index				
	0	1	2	3	...
1	$\frac{1}{2} \begin{bmatrix} 1 \\ 1 \\ 1 \\ -1 \end{bmatrix}$	$\frac{1}{2} \begin{bmatrix} 1 \\ 1 \\ j \\ j \end{bmatrix}$	$\frac{1}{2} \begin{bmatrix} 1 \\ 1 \\ -1 \\ 1 \end{bmatrix}$	$\frac{1}{2} \begin{bmatrix} 1 \\ 1 \\ -j \\ -j \end{bmatrix}$	...
2	$\frac{1}{2} \begin{bmatrix} 1 & 0 \\ 1 & 0 \\ 0 & 1 \\ 0 & -j \end{bmatrix}$	$\frac{1}{2} \begin{bmatrix} 1 & 0 \\ 1 & 0 \\ 0 & 1 \\ 0 & j \end{bmatrix}$	$\frac{1}{2} \begin{bmatrix} 1 & 0 \\ -j & 0 \\ 0 & 1 \\ 0 & 1 \end{bmatrix}$	$\frac{1}{2} \begin{bmatrix} 1 & 0 \\ -j & 0 \\ 0 & 1 \\ 0 & -1 \end{bmatrix}$	...
3	$\frac{1}{2} \begin{bmatrix} 1 & 0 & 0 \\ 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix}$	$\frac{1}{2} \begin{bmatrix} 1 & 0 & 0 \\ -1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix}$	$\frac{1}{2} \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 1 & 0 & 0 \\ 0 & 0 & 1 \end{bmatrix}$	$\frac{1}{2} \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ -1 & 0 & 0 \\ 0 & 0 & 1 \end{bmatrix}$	...
4	$\frac{1}{2} \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$	—	—	—	...

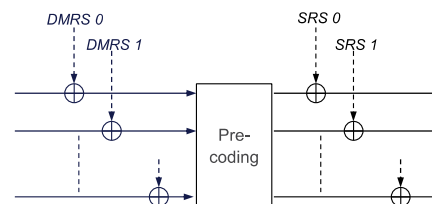


FIGURE 7.20

Illustration of SRS transmitted *after* uplink antenna precoding.

(Section 7.2.2). As indicated in Figure 7.20 SRS are transmitted non-precoded—that is, directly on the different antenna ports. The received SRS thus reflect the channel of each antenna port, not including any precoding. Based on the received SRS, the network can thus decide on a suitable uplink transmission rank and corresponding uplink precoder matrix, and provide information about the selected rank and precoder matrix as part of the scheduling grant.

The previous paragraph assumed the same number of antenna ports for PUSCH as for SRS. This is a relevant situation and the SRS is, in this case, used to aid the selection of the precoding matrix, as discussed in the preceding paragraphs. However, there are also situations when SRS and PUSCH use *different* numbers of antenna ports. One example is uplink transmission of two layers (two antenna ports), where the eNodeB would like to use SRS to probe the channel for potential four-layer transmission. In this case the SRS is transmitted on a *different* set of antenna ports than the PUSCH to aid the eNodeB in assessing the benefits, if any, of switching to four-layer transmission.

Dahlman 4G Advanced Pro pp 191-193.

In LTE, “the first burst data signal is “the sounding reference symbol” (SRS), which is used by the eNodeB to measure channel characteristics and determine suitable precoding matrices.

For each UE, the eNodeB determines (based on the SRS, number of layers, and number of antenna ports to be used) and stores an appropriate precoding matrix and communicates the index of the precoding matrix to the UE. The precoding matrix is then used to transmit the uplink signal and the eNodeB uses the same precoding matrix to decode the uplink signal.

Similarly, 5G/NR selects a codebook for each uplink precoded transmission based in part on the number and configuration of antennas on the UE:

“To select a suitable rank and a corresponding precoder matrix, the network needs estimates of the channels between the device antenna ports and the corresponding network receive antennas. To enable this, a device configured for codebook-based PUSCH would typically be configured for transmission of at least one multi-port SRS. Based on measurements on the configured SRS, the network can sound the channel and determine a suitable rank and precoder matrix.

“The network cannot select an arbitrary precoder. Rather, for a given combination of number of antenna ports N_T ($N_T = 2$ or $N_T = 4$) and transmission rank N_L ($N_L \leq N_T$), the network selects the precoder matrix from a limited set of available precoders (the “uplink codebook”).

As an example, Fig. 11.10 illustrates the available precoder matrices, that is, the code books for the case of two antenna ports.



FIG. 11.10 Uplink codebooks for the case of two antenna ports.

“When selecting the precoder matrix, the network needs to consider the device capability in terms of antenna-port coherence (see earlier). For devices not supporting coherence, only the first two precoder matrixes can therefore be used in the case of single-rank transmission.

It can be noted that restricting the codebook selection to these two matrices is equivalent to selecting either the first or second antenna port for transmission. In the case of such antenna selection, a well-controlled phase, that is, coherence between the antenna ports is not required. On the other hand, the remaining precoder vectors imply linear combination of the signals on the different antenna ports, which requires coherence between the antenna ports.”

Excerpt From 5G NR, Erik Dahlman, Stefan Parkvall, Johan Skold.

8. The apparatus of claim 1 wherein the signal-related parameter is representative of a signal characteristic of the first burst data signal transmitted over the first channel.

See disclosure for Claim 1. In addition, the signal-related parameter is representative of a signal characteristic of the first burst data signal transmitted over the first channel, in that such parameters include the amount of forward error correction (FEC) of the burst, change in frequency of the burst, changes in time of the burst, changes in power levels of the burst, etc., and/or other signal-related parameters that are representative of a signal characteristic of the first burst data signal transmitted over the first channel.

9. The apparatus of claim 8 wherein the signal-related parameter

See disclosure for Claim 8. In addition, the signal-related parameter determined by the profile parameter determiner comprises a value representative of a frequency characteristic of the first burst data signal when each UE is assigned “resource blocks” in which to send uplink transmissions. This process may be started in the Random Access Channel (RACH), and otherwise updated thereafter, to allow UEs to synchronize to the eNodeB and connect to the network. The UE transmits the

determined by said profile parameter determiner comprises a value representative of a frequency characteristic of the first burst data signal.	selected preamble sequence on the RACH, and the eNodeB uses the signal to detect the UE and estimate transmission correction parameters including timing and power for the UE, as well as frequency. The eNodeB then assigns resources to the UE via the PDCCH (physical downlink control channel) and transmits a response to the UE on the DL-SCH (downlink shared channel). This response includes the resource allocation for the UE as well as uplink timing and transmit power adjustments for the UE based on the measurement performed. This timing measurement and adjustment process is performed for each UE as each requires a timing offset and transmit power adjustment unique to its location relative to the eNodeB, and it takes place over the RACH. The eNodeB defines the resource blocks to be used for RACH and periodically broadcasts those parameters on the control channel. This is how a new UE learns the pool of available random preambles to choose from and how it knows when to transmit the RACH signal.) 3GPP 36.331 describes the RACH parameters describing the RACH configuration broadcast by the eNodeB. See 3GPP TS 36.331 14.16.0 pg. 427 for the RACH-ConfigCommon information element and pg. 428 for the RACH-ConfigCommon field descriptions. The Random Access procedure is described in 3GPP TS 36.321 version 14.13.0 §5.1. T-Mobile 4G and 5G base stations use the profile parameter determiner to determine a value representative of a frequency characteristic as the signal-related parameter in the processors as described above and as depicted in Ahmadi 5G NR Figure 4.72 (above). Based on additional transmissions from the UE, subsequent parameter determinations are made by the profile parameter determiner that comprise a value representative of a frequency characteristic of the first burst data signal.
10. The apparatus of claim 8 wherein the signal-related parameter determined by said profile parameter determiner comprises a value representative of a time-shift characteristic of the first burst data signal.	See disclosure for Claim 8. In addition, the signal-related parameter determined by the profile parameter determiner comprises a value representative of a time-shift characteristic of the first burst data signal. This process may be started in the Random Access Channel (RACH), and otherwise updated thereafter, to allow UEs to synchronize to the eNodeB and connect to the network. The UE transmits the selected preamble sequence on the RACH, and the eNodeB uses the signal to detect the UE and estimate transmission correction parameters including timing and power for the UE, as well as frequency. The eNodeB then assigns resources to the UE via the PDCCH (physical downlink control channel) and transmits a response to the UE on the DL-SCH (downlink shared channel). This response includes the resource allocation for the UE as well as uplink timing and transmit power adjustments for the UE based on the measurement performed. This timing measurement and adjustment process is performed for each UE as each requires a timing offset and transmit power adjustment unique to its location relative to the eNodeB, and it takes place over the RACH during a contention period. The eNodeB defines the resource blocks to be used for RACH and periodically broadcasts those parameters on the control channel. This is how a new UE learns the pool of available random preambles to choose from and how it knows when to transmit the RACH signal.) 3GPP 36.331 describes the RACH parameters describing the RACH configuration broadcast by the eNodeB. See 3GPP TS 36.331 14.16.0 pg. 427 for the RACH-ConfigCommon information element and pg. 428 for the RACH-ConfigCommon field descriptions. The Random Access procedure is described in 3GPP TS 36.321 version 14.13.0 §5.1. T-Mobile 4G and 5G base stations use the profile parameter determiner to determine a value representative of a time-shift characteristic as the signal-

	related parameter in the processors as described above and as depicted in Ahmadi 5G NR Figure 4.72 (above). Based on additional transmissions from the UE, subsequent parameter determinations are made by the profile parameter determiner that comprise a value representative of a time shift characteristic of the first burst data signal.
11. The apparatus of claim 8 wherein the first burst data signal includes forward error correction (FEC) and wherein the signal-related parameter determined by said profile parameter determiner comprises a value representative of the FEC included in the first burst data signal.	See disclosure for Claim 8. In addition, the first burst data signal includes forward error correction (FEC), and a signal-related parameter determined by said profile parameter determiner comprises a value representative of the FEC included in the first burst data signal. T-Mobile's 4G and 5G base stations include a first burst data signal that includes FEC (forward error correction). For example, and without limitation, the following figure from Ahmadi identifies forward error correction utilizing an LDPC code:

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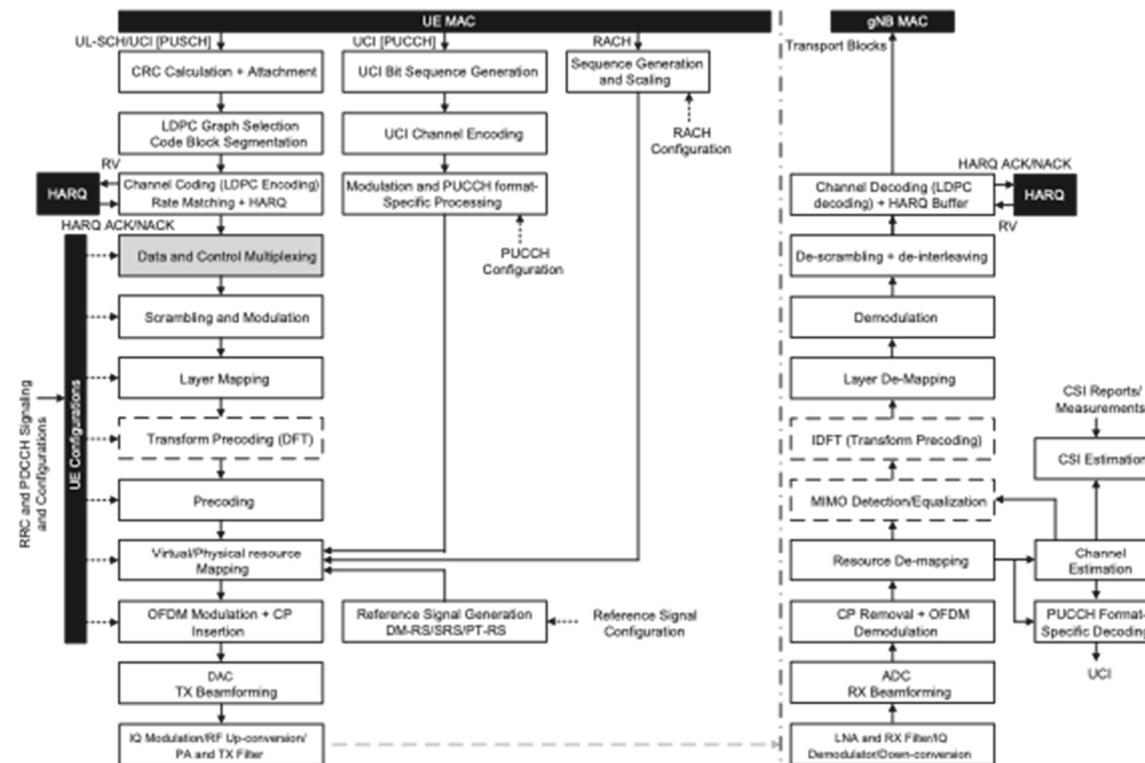


Figure 4.72
Overall uplink physical layer processing [5].

Ahmadi 5G NR, Figure 4.72. See also Dahlman 5G at 165 (noting that, in 5G transmissions, including uplink transmissions on the UL-SCH, “[a] CRC for error-detecting purposes is added to each transport block, followed by error-correcting codes using LDPC codes”); *id.* at Section 9.2.3 (discussing the LDPC codes used in 5G). See also <https://ieeexplore.ieee.org/abstract/document/8477009> (discussing the LDPC codes used in 5G). While these sources indicate that CRC and LDPC codes are used with 5G, other forward error correction codes would similarly meet the limitations. In addition, 5G NR utilizes Hybrid ARQ forward error correction techniques. See, e.g., Ahmadi 5G at Section 4.1.8 (discussing HARQ, which combines “ARQ error-control mechanism[s] and FEC coding.”). When utilizing HARQ, the

transmissions from the UEs are encoded with FEC. The FEC (and related data) are then stored by the controller. Similarly, uplink transmissions in 4G LTE utilize FEC. *See, e.g.*, Dahlman 4G at Sections 10.1.1.2 and 10.1.1.3 (discussing “channel coding” in LTE that utilizes turbo FEC codes, as well as CRC encoding for error detection, both of which entail parameters that would be maintained and stored by the controller); *see also id.* at 11.1 (discussing uplink transmissions in LTE, including the use of FEC turbo and CRC codes).

Uplink transmissions in 4G LTE also utilize Hybrid ARQ. *See, e.g.*, Dahlman 4G at 97 “Virtually all modern communication systems, including LTE, employ a combination of forward error-correction coding and ARQ, known as hybrid ARQ.”); *id.* at 98 (“In hybrid ARQ with soft combining, the erroneously received packet is stored in a buffer memory and later combined with the retransmission to obtain a single, combined packet that is more reliable than its constituents. Decoding of the error-correction code operates on the combined signal. If the decoding fails (typically a CRC code is used to detect this event), a retransmission is requested.”); *id.* at Section 11.4.2.3 (discussing uplink HARQ).

Parameters related to FEC, including but not limited to code rate, puncturing, and shortening parameters form portions of the profiles maintained and stored. *See also* Harri Holma, Antti Toskala, and Takehiro Nakamura, 5G Technology, Wiley, Kindle Edition at 134-35 (discussing the importance of FEC in 5G, and the importance of selecting flexible FEC capable of operating with a variable code length, code rate, and HARQ): Channel coding is one of the main hardware critical components in 5G, and codes used in 5G are capable of providing good performance gains with a lower implementation complexity and processing delays compared to its predecessors. In 3GPP Rel-15, different service scenarios were considered in the initial phase of the channel coding discussion; however, the final selection of the channel coding scheme was mainly decided based on the eMBB requirements, which were identified as performance of the coding scheme, implementation complexity, the latency of encoding and decoding, and the flexibility (e.g. variable code length, code rate, HARQ) of the coding scheme. *Id.* at 135: LDPC is a very mature coding scheme which has been considered by many other standards. The flexibility that the coding scheme provided in implementations together with competitive performance can be identified as one of the key advantages that LDPC possesses when compared to all other coding schemes.

In addition, 5G NR utilizes Hybrid ARQ forward error correction techniques. *See, e.g.*, Ahmadi 5G at Section 4.1.8 (discussing HARQ, which combines “ARQ error-control mechanism[s] and FEC coding”). When utilizing HARQ, the transmissions from the UEs are encoded with FEC. The FEC (and related data) are then stored by the controller, where they form portions of the profiles maintained by the controller and stored at the memory portion of the controller. *See id.* at 540:

The drawbacks of ARQ and FEC can be overcome, if the two error control schemes are properly combined. In order to achieve increased throughput and lower latency in packet transmission, hybrid ARQ (HARQ) scheme was designed to combine ARQ error-control mechanism and FEC coding. A HARQ system consists of a FEC subsystem contained in an ARQ system. In this approach, the average number of retransmissions is reduced by using FEC through correction of the error patterns that occur more frequently; however, when the less frequent error patterns are detected, the receiver requests a retransmission where each retransmission carries the same or some redundant information to help the packet detection. The HARQ uses FEC to correct a subset of errors at the receiver and rely on error detection to detect the remaining errors. Most practical HARQ schemes utilize CRC codes for error detection and some form of FEC for correcting the transmission errors. The HARQ schemes

Id. at 542:

3GPP NR uses an asynchronous HARQ-IR scheme in the downlink and uplink. The gNB provides the UE with the HARQ-ACK feedback timing either dynamically in the DCI or semi-statically through RRC configuration messages. The gNB schedules each uplink transmission and retransmission using the uplink grant on DCI. In LTE, the basic mode of operation for uplink HARQ is synchronous retransmission, which can be used to reduce the scheduling overhead for retransmissions. In this case, HARQ ACK/NACK is carried on PHICH as a short and efficient message. In NR, asynchronous HARQ is supported. In order to support asynchronous HARQ, a straightforward solution for the gNB is to send an explicit uplink grant through PDCCH for the retransmission in the same way that is done for transmissions in LTE. In some sense, the explicit grant can imply an implicit ACK/NACK. For example, an explicit scheduling grant of a retransmission may imply a NACK for the initial transmission. The maximum number of HARQ processes in the downlink and uplink per cell is 16. The number of HARQ processes is separately configured for the UE for each cell by RRC parameter *nrofHARQ-processesForPDSCH*. In the absence of any configuration, the UE may assume a default number of 8 HARQ processes.

Id. at 542:

	The UE must provide a valid HARQ-ACK message, if the first uplink symbol of PUCCH conveying the HARQ-ACK information, as identified by HARQ-ACK timing parameter K_1 and the assigned PUCCH resource including the effect of the timing advance, starts on or after symbol L_1, that is, the next uplink symbol with its cyclic prefix starting after $T_{proc} = 2192(N_1 + d_x) \kappa 2^{-\mu} T_c$ (processing time) following the end of the last symbol of the PDSCH carrying the transport block being acknowledged. As shown in Fig. 4.55, parameter N_1 is based on the numerology and corresponds to $(\mu_{PDCCH}, \mu_{PDSCH}, \mu_{UL})$ where μ_{PDCCH}, μ_{PDSCH}, and μ_{UL} correspond to the subcarrier spacing of the PDCCH scheduling, PDSCH transmission, and the uplink channel on which the HARQ-ACK is transmitted, respectively. As shown in Table 4.18, the value of parameter N_1 further depends on the PDSCH DM-RS pattern and whether additional DM-RS is used as well as UE PDSCH processing capability. The value of parameter d_x is dependent on the PDSCH mapping type (A or B), UE PDSCH processing capability, and the number of PDSCH symbols [9]. The timing relationship between HARQ-ACK and PDSCH data transmission depends on the value of the above parameters and is depicted in Fig. 4.55. <i>Id.</i> at 544: In the NR downlink, retransmissions are scheduled in the same way as new data, that is, they may occur at any time and at an arbitrary frequency location within the downlink cell bandwidth. The scheduling assignment contains the necessary HARQ-related control signaling such as process number, new-data indicator, CBGTI, and CBGFI in case of CBG-based retransmission as well as information to handle the transmission of the acknowledgment in the uplink such as timing and resource indication. Upon receiving a scheduling assignment ... The NR uplink uses asynchronous HARQ protocol in the same way as downlink. The HARQ-related information including process number, new-data indicator, CBG-based retransmission (if configured), and the CBGTI are included in the scheduling grant. The uplink CBGTI is used in the same way as in the downlink, that is, to indicate the CBGs that need to be retransmitted in the case of CBG-based retransmission. Note that no CBGFI is needed in the uplink as the soft buffer is located in the gNB which can decide whether to flush the buffer or not based on the scheduling decisions.
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Similarly, uplink transmissions in 4G LTE utilize FEC. *See, e.g.*, Dahlman 4G at Sections 10.1.1.2 and 10.1.1.3 (discussing “channel coding” in LTE that utilizes turbo FEC codes, as well as CRC encoding for error detection, both of which entail parameters that would be maintained and stored by the controller); *see also id.* at 11.1 (discussing uplink transmissions in LTE, including the use of FEC turbo and CRC codes). Uplink transmissions in 4G LTE also utilize Hybrid ARQ. *See, e.g.*, Dahlman 4G at 97 “Virtually all modern communication systems, including LTE, employ a combination of forward error-correction coding and ARQ, known as hybrid ARQ.”); *id.* at 98 (“In hybrid ARQ with soft combining, the erroneously received packet is stored in a buffer memory and later combined with the retransmission to obtain a single, combined packet that is more reliable than its constituents. Decoding of the error-correction code operates on the combined signal. If the decoding fails (typically a CRC code is used to detect this event), a retransmission is requested.”); *id.* at Section 11.4.2.3 (discussing uplink HARQ).

3GPP TS 38.214 version 16.11.0 Release 16 also includes tables 5.1.3.1-1.3 for the DL, and correspondingly the same tables in §6.1.4 for the UL that show the target code rate or FEC and how the UE reads the DCI from the gNodeB and extracts things like MCS to use in the UL transmission. An example of such a table is below.

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ETSI TS 138 214 V16.11.0 (2022-09)

Table 5.1.3.1-2: MCS index table 2 for PDSCH

MCS Index <i>I_{MCS}</i>	Modulation Order <i>Q_m</i>	Target code Rate <i>R</i> x [1024]	Spectral efficiency
0	2	120	0.2344
1	2	193	0.3770
2	2	308	0.6016
3	2	449	0.8770
4	2	602	1.1758
5	4	378	1.4766
6	4	434	1.6953
7	4	490	1.9141
8	4	553	2.1602
9	4	616	2.4063
10	4	658	2.5703
11	6	466	2.7305
12	6	517	3.0293
13	6	567	3.3223
14	6	616	3.6094
15	6	666	3.9023
16	6	719	4.2129
17	6	772	4.5234
18	6	822	4.8164
19	6	873	5.1152
20	8	682.5	5.3320
21	8	711	5.5547
22	8	754	5.8906
23	8	797	6.2266
24	8	841	6.5703
25	8	885	6.9141
26	8	916.5	7.1602
27	8	948	7.4063
28	2	reserved	
29	4	reserved	
30	6	reserved	
31	8	reserved	

	T-Mobile 4G and 5G base stations use the profile parameter determiner to determine a value representative of a FEC as the signal-related parameter in the processors as described above and as depicted in Ahmadi 5G NR Figure 4.72 (above).
12. The apparatus of claim 8 wherein the signal related parameter determined by said profile parameter determiner comprises a value related to power-levels of the first burst data signal.	See disclosure for Claim 8. In addition, the signal-related parameter determined by the profile parameter determiner comprises a value related to power levels of the first burst data signal when each UE is assigned “resource blocks” in which to send uplink transmissions. This process may be started in the Random Access Channel (RACH), and otherwise updated thereafter, to allow UEs to synchronize to the eNodeB and connect to the network. The UE transmits the selected preamble sequence on the RACH, and the eNodeB uses the signal to detect the UE and estimate transmission correction parameters including timing and power for the UE, as well as frequency. The eNodeB then assigns resources to the UE via the PDCCH (physical downlink control channel) and transmits a response to the UE on the DL-SCH (downlink shared channel). This response includes the resource allocation for the UE as well as uplink timing and transmit power adjustments for the UE based on the measurement performed. This timing measurement and adjustment process is performed for each UE as each requires a timing offset and transmit power adjustment unique to its location relative to the eNodeB, and it takes place over the RACH during a contention period. The eNodeB defines the resource blocks to be used for RACH and periodically broadcasts those parameters on the control channel. This is how a new UE learns the pool of available random preambles to choose from and how it knows when to transmit the RACH signal.) 3GPP 36.331 describes the RACH parameters describing the RACH configuration broadcast by the eNodeB. See 3GPP TS 36.331 14.16.0 pg. 427 for the RACH-ConfigCommon information element and pg. 428 for the RACH-ConfigCommon field descriptions. The Random Access procedure is described in 3GPP TS 36.321 version 14.13.0 §5.1. The eNodeB updates the transmit power on an ongoing basis as shown in the DCI transmit power control commands along with the uplink allocation singled to the UE when the eNodeB schedules uplink for each user, as described in 3GPP TS 38.213 version 16.11.0, Section 7, along with Section 4.2 describing timing adjustments associated therewith. Transmit Power Control 3GPP TS 38.213 version 16.11.0: §7 Uplink Power control determines a power for PUSCH, PUCCH, SRS, and PRACH transmissions.

	• §7.1 describes behaviour in response to the DCI • §7.1.1 describes UE behaviour ◦ Table 7.1.1-1 shows the TPC command field mapping to accumulated and absolute values. My understanding is that accumulated mode is like a fine tuning while absolute allows for larger jumps in power change. • §7.4 describes use on the RACH - this describes the power ramping I described T-Mobile 4G and 5G base stations use the profile parameter determiner to determine a value related to power-levels as the signal-related parameter in the processors as described above and as depicted in Ahmadi 5G NR Figure 4.72 (above).
13. The apparatus of claim 1 wherein said profile parameter determiner is further coupled to receive an indication of at least one additional burst of the first burst data signal, said profile parameter determiner further for determining an updated value of the at least one parameter responsive to the at least one additional	See disclosure for Claim 8. In addition, the signal-related parameter determined by the profile parameter determiner comprises a value related to power levels of the first burst data signal when each UE is assigned “resource blocks” in which to send uplink transmissions. This process may be started in the Random Access Channel (RACH), and otherwise updated thereafter, to allow UEs to synchronize to the eNodeB and connect to the network. The UE transmits the selected preamble sequence on the RACH, and the eNodeB uses the signal to detect the UE and estimate transmission correction parameters including timing and power for the UE, as well as frequency. The eNodeB then assigns resources to the UE via the PDCCH (physical downlink control channel) and transmits a response to the UE on the DL-SCH (downlink shared channel). This response includes the resource allocation for the UE as well as uplink timing and transmit power adjustments for the UE based on the measurement performed. This timing measurement and adjustment process is performed for each UE as each requires a timing offset and transmit power adjustment unique to its location relative to the eNodeB, and it takes place over the RACH during a contention period. The eNodeB defines the resource blocks to be used for RACH and periodically broadcasts those parameters on the control channel. This is how a new UE learns the pool of available random preambles to choose from and how it knows when to transmit the RACH signal.) 3GPP 36.331 describes the RACH parameters describing the RACH configuration broadcast by the eNodeB. See 3GPP TS 36.331 14.16.0 pg. 427 for the RACH-ConfigCommon information element and pg. 428 for the RACH-ConfigCommon field descriptions. The Random Access procedure is described in 3GPP TS 36.321 version 14.13.0 §5.1. The eNodeB updates the transmit power on an ongoing basis as shown in the DCI transmit power control commands along with the uplink allocation singled to the UE when the eNodeB schedules uplink for each user, as described in shown in 3GPP TS 38.213 version 16.11.0, Section 7, along with Section 4.2 describing timing adjustments associated therewith.

burst of the first burst signal.	Transmit Power Control 3GPP TS 38.213 version 16.11.0: §7 Uplink Power control • determines a power for PUSCH, PUCCH, SRS, and PRACH transmissions. • §7.1 describes behaviour in response to the DCI • §7.1.1 describes UE behaviour ○ Table 7.1.1-1 shows the TPC command field mapping to accumulated and absolute values. My understanding is that accumulated mode is like a fine tuning while absolute allows for larger jumps in power change. • §7.4 describes use on the RACH - this describes the power ramping I described This is one example, among others, where T-Mobile 4G and 5G base stations use a profile parameter determiner to receive an indication of at least one additional burst of the first burst data signal, and where the profile parameter determiner determines an updated value of one parameter responsive to one additional burst of the first burst signal. Other signal-related and channel-related parameters are discussed elsewhere in these contentions. The profile parameter determiner updates the profile to include updated signal and/or channel related parameters and stores such updates at the memory device so that when subsequent bursts are transmitted from the UEs to the receiving station the updated profile is utilized to improve the data signal. For example, and without limitation, one technique known as cyclo-stationary adaptive filtering can be performed on the uplink data burst to update the values. By updating and using the profiles the speed and accuracy of the operations can be improved on subsequent bursts of data and subsequent updates.
14. The apparatus of claim 13 wherein the receiving station is operable in a communication	See disclosure for Claims 2 and 13. In addition, the T-Mobile receiving station is operable in a communication system in which communication protocols include a contention period and wherein the initial burst and the at least one additional burst of the first burst data signal, responsive to which said profile parameter determiner determines the at least on parameter is communicated during the contention period.

system in which communication protocols include a contention period and wherein the initial burst and the at least one additional burst of the first burst data signal, responsive to which said profile parameter determiner determines the at least one parameter is communicated during the contention period.	The UE may continue to communicate subsequent bursts during the contention period to the base station by which the profile parameter determiner determines the one parameter communicated during the contention period.
15. The apparatus of claim 1 wherein at least the first burst data signal transmitted upon the at least the first channel comprises a plurality of burst data signals transmitted upon a plurality of channels and wherein said profile parameter determiner	See disclosure for Claim 1. In addition, T-Mobile 4G and 5G base stations have a first burst data signal transmitted upon the first channel with a plurality of burst data signals transmitted on a plurality of channels, and the profile parameter determiner further determines a value of a plurality of parameters representative of communication of the plurality of burst data signals on the plurality of channels. For example, and without limitation, uplink Single-User MIMO, as well as Multi-User MIMO, is a technique deployed in LTE and 5G/NR where a plurality of burst signals are transmitted by one or more UEs. The various paths from each of the UEs to the T-Mobile base station are a plurality of channels. In order to receive a plurality of transmissions sent from one or more of UEs, each UE is configured to apply a precoding matrix to the signals it is sending. This precoding allows the T-Mobile base station to apply the opposite process to separate the various transmissions. For LTE, Dahlman explains:

determines a value of a plurality of parameters representative of communication of the plurality of burst data signals and each of the plurality of channels.

7.3.2 UPLINK MULTI-USER MIMO

As described in Section 6.3.5, downlink multi-user MIMO (MU-MIMO) implies downlink transmission to different devices using *the same time–frequency resource* and relying on the availability of multiple antennas, at least on the network side, to suppress interference between the transmissions. The term MU-MIMO originated from the resemblance to SU-MIMO (spatial multiplexing).

Uplink MU-MIMO is essentially the same thing but for the uplink transmission direction—that is, uplink MU-MIMO implies uplink transmissions from multiple devices using *the same uplink time–frequency resource* and relying on the availability of multiple receive antennas at the base station to separate the two or more transmissions. Thus, MU-MIMO is really just another term for uplink *space-division multiple access* (SDMA).

See Dahlman, 4G LTE-Advanced Pro (2016) pg. 193

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Actually, on the uplink, the relation between MU-MIMO and SU-MIMO (spatial multiplexing) is even closer. Uplink spatial multiplexing, for example with two antenna ports and two layers, implies that the device transmits two transport blocks with one transport block transmitted on each layer and thus on each antenna port,¹⁴ as illustrated in the left part of Figure 7.21. As illustrated in the right part of the figure, MU-MIMO is essentially equivalent to separating the two antennas into two different devices and transmitting one transport block from each device. The base-station processing to separate the two

transmissions could essentially be identical to the processing used to separate the two layers in the case of spatial multiplexing. It should be noted that the separation of the two transmissions at the receiver side could be simplified, or at least the possible means to achieve this separation are extended, if the two devices are well separated in space, something which is not the case for two antennas attached to the same device. As an example, for sufficiently separated devices, classical beam-forming relying on correlated receiver antennas can be used to separate the uplink transmissions. Alternatively, uncorrelated receiver antennas can be used, and the separation means are then essentially the same as for SU-MIMO.

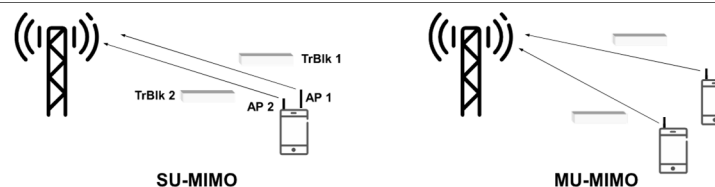


FIGURE 7.21

SU-MIMO and MU-MIMO.

¹⁴Note that the 2×2 precoder matrix is the identity matrix, see Table 7.1.

See Dahlman, 4G LTE-Advanced Pro (2016) pp. 193-194

Similarly, for 5G/NR, uplink precoding is described in Dahlman:

“11.3: NR Uplink Multi-Antenna Precoding

NR support uplink (PUSCH) multi-antenna precoding with up to four layers. However, as mentioned earlier, in the case of DFT-based transform precoding (see Chapter 9) only single-layer transmission is supported.

The device can be configured in two different modes for PUSCH multi-antenna precoding, referred to as codebook-based transmission and non-codebook-based transmission respectively. The selection between these two transmission modes is at least partly depending on what can be assumed in terms of uplink/downlink channel reciprocity, that is, to what extent it can be assumed that the detailed uplink channel conditions can be estimated by the device based on downlink measurements.”

Excerpt From 5G NR Erik Dahlman, Stefan Parkvall, Johan Skold pg. 256.

“11.3.1: Codebook-Based Transmission

The basic principle of codebook-based transmission is that the network decides on an uplink transmission rank, that is, the number of layers to be transmitted, and a corresponding precoder matrix to use for the transmission. The network informs the device about the selected transmission rank and precoder matrix as part of the uplink scheduling grant. At the device side, the precoder matrix is then applied for the scheduled PUSCH transmission, mapping the indicated number of layers to the antenna ports.

To select a suitable rank and a corresponding precoder matrix, the network needs estimates of the channels between the device antenna ports and the corresponding network receive antennas. To enable this, a device configured for codebook-based PUSCH would typically be configured for transmission of at least one multi-port SRS. Based on measurements on the configured SRS, the network can sound the channel and determine a suitable rank and precoder matrix.”

Excerpt From 5G NR Erik Dahlman, Stefan Parkvall, Johan Skold pg. 257.

“11.3.2: Non-Codebook-Based Precoding

In contrast to codebook-based precoding, which is based on network measurements and selection of uplink precoder, non-codebook-based precoding is based on device measurements and precoder indications to the network. The basic principle of uplink non-codebook-based precoding is illustrated in Fig. 11.13 with further explanation below.

Fig. 11.13 Non-codebook-based precoding.

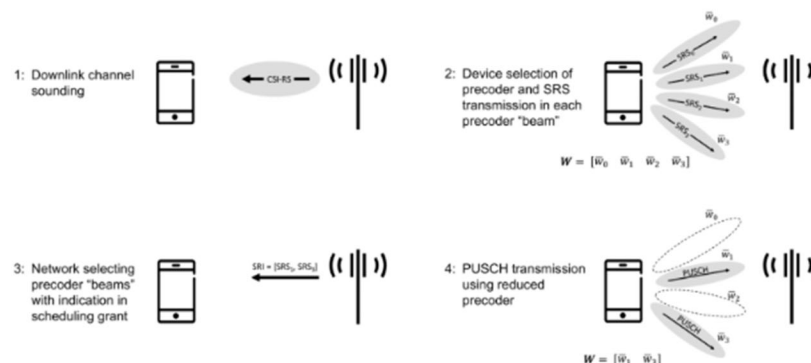


FIG. 11.13 Non-codebook-based precoding.

Based on downlink measurements, in practice measurements on a configured CSI-RS, the device selects what it believes is a suitable uplink multi-layer precoder. Non-codebook-based precoding is thus based on an assumption of channel reciprocity, that is, that the device can acquire detailed knowledge of the uplink channel based on downlink measurements. Note that there are no restrictions on the device selection of precoder, thus the term “non-codebook-based.”

	<i>“Each column of a precoder matrix W can be seen as defining a digital “beam” for the corresponding layer. The device selection of precoder for NL layers can thus be seen as the selection of NL different beam directions where each beam corresponds to one possible layer.</i> <i>In principle, PUSCH transmission could be done directly as transmission of NL layers based on the device-selected precoding. However, device selection of a precoder based on downlink measurements may not necessarily be the best precoder from a network point of view. Thus, the NR non-codebook-based precoding includes an additional step where the network can modify the device-selected precoder, in practice remove some “beams,” or equivalently some columns, from the selected precoder.”</i> Excerpt From 5G NR Erik Dahlman, Stefan Parkvall, Johan Skold pp. 260-261.
16. A method for creating at least a first profile associated with transmission upon at least a first channel of at least a first burst data signal in bursts to a receiving station, said method comprising:	To the extent that the preamble may be considered a limitation, T-Mobile 4G and 5G base stations perform the method as described in Claim 16 because they create a profile associated with transmission upon at least a first channel of a first burst data signal in bursts to a receiving station. See disclosures for Claim 1, which are incorporated here by reference.
responsive to reception at the receiving station of an initial burst of the first burst data signal transmitted upon the first channel, determining a value	T-Mobile 4G and 5G base stations are responsive at the receiving station of an initial burst of the first burst data signal transmitted on the first channel, and determining a value of at least one signal-related parameter and channel-related parameter. See disclosures for Claim 1.1, which are incorporated here by reference.

of at least one signal-related parameter and at least one channel-related parameter,	
wherein the signal-related and channel-related parameters are collectively representative of communication of the first burst data signal over the first channel to the receiving station;	T-Mobile 4G and 5G base stations have signal-related and channel-related parameters that are collectively representative of communication of the first burst data signal over the first channel to the receiving station. See disclosures for Claim 1.2, which are incorporated here by reference.
storing values representative of the at least one signal-related parameter and the at least one channel-related parameter determined during said operation of determining; and	T-Mobile 4G and 5G base stations store values representative of at least one signal-related parameter and channel-related parameter determined during operation. See disclosures for Claim 1.3, which are incorporated here by reference.

using the values stored during said operation of storing to facilitate receive operations performed at the receiving station upon at least one subsequent burst of the first burst data signal.	T-Mobile 4G and 5G base stations use the values stored during operation to facilitate receive operations performed at the receiving station on the one subsequent burst of the first burst data signal. See disclosures for Claim 1.3, which are incorporated here by reference.
17. The method of claim 16 further comprising the operations of: detecting, at the receiving station, the at least one subsequent burst of the first burst data signal; responsive to detecting the at least one subsequent burst, updating the previously-determined value(s) of one or both of the at least one signal-related	See disclosure for Claims 1, 13 & 16, which are incorporated here by reference.

parameter and the at least one channel-related parameter.	
18. The method of claim 16 wherein the receiving station is operable in a communication system in which communication protocols include a contention period and wherein the initial burst of the first burst data signal responsive to which the at least one signal-related parameter and the at least one channel-related parameter are determined is transmitted to the receiving station during the contention period.	See disclosures for Claims 2 & 16, which are incorporated here by reference.
19. The method of claim 16 wherein	See disclosures for Claims 5-6 & 16, which are incorporated here by reference.

the at least channel-related parameter comprises one or more of equalization weighting and antenna parameters.	
20. The method of claim 16 wherein the at least signal-related parameter comprises one or more of forward error correction (FEC) amount, frequency change, burst time change, and burst power level change.	See disclosures for Claims 9-12 & 16, which are incorporated here by reference.