(12) UK Patent (19) GB (11) 2572390 (13) B

(45) Date of B Publication 10.03.2021

(54) Title of the Invention: Reference signal power boosting in a telecommunication system

(51) INT CL: ***H04W 52/32*** (2009.01) ***H04W 52/14*** (2009.01) ***H04W 52/34*** (2009.01)

(21) Application No: **1805051.8**

(22) Date of Filing: **28.03.2018**

(43) Date of A Publication **02.10.2019**

(56) Documents Cited:
3GPP Draft; R1-1719543; RAN WG1; 18th November 2017; Mobile Competence Centre, 650, route des Lucioles, F-06921 Sophia-Antipolis Cedex, France; ZTE, Sanechips; "Remaining details on PT-RS"

(58) Field of Search:
As for published application 2572390 A viz:
INT CL **H04W**
Other: **EPODOC, WPI, XP3GPP, Patent Fulltext**
updated as appropriate

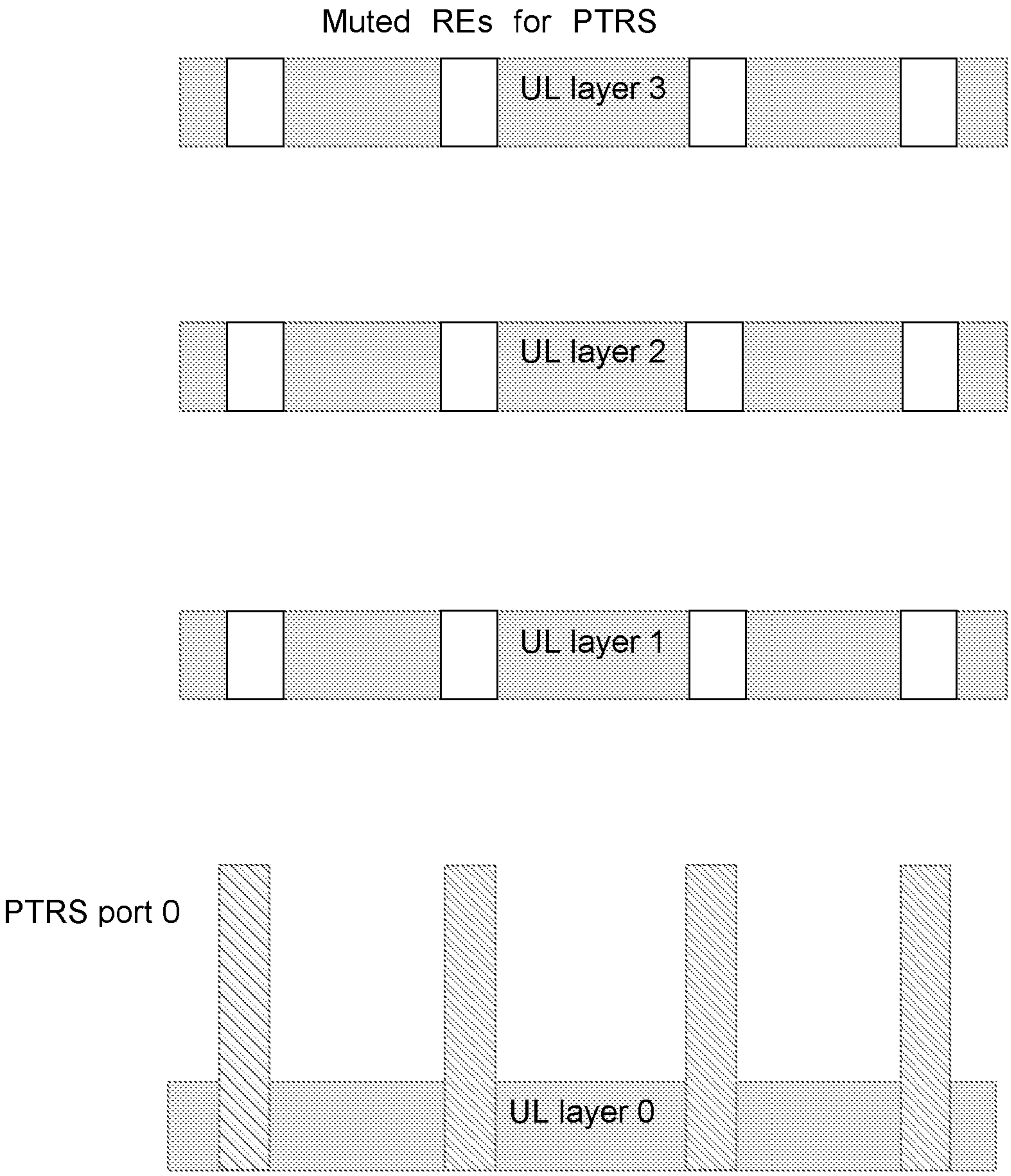
Additional Fields
INT CL **H04L**
Other: **None**

(72) Inventor(s):
Yinan Qi

(73) Proprietor(s):
Samsung Electronics Co., Ltd.
129, Samsung-ro, Yeongtong-gu, Suwon-si, Gyeonggi-do 16677, Republic of Korea

(74) Agent and/or Address for Service:
Appleyard Lees IP LLP
15 Clare Road, HALIFAX, West Yorkshire, HX1 2HY, United Kingdom

GB 2572390 B



Muted REs for PTRS
UL layer 3
UL layer 2
UL layer 1
PTRS port 0
UL layer 0

Fig. 1

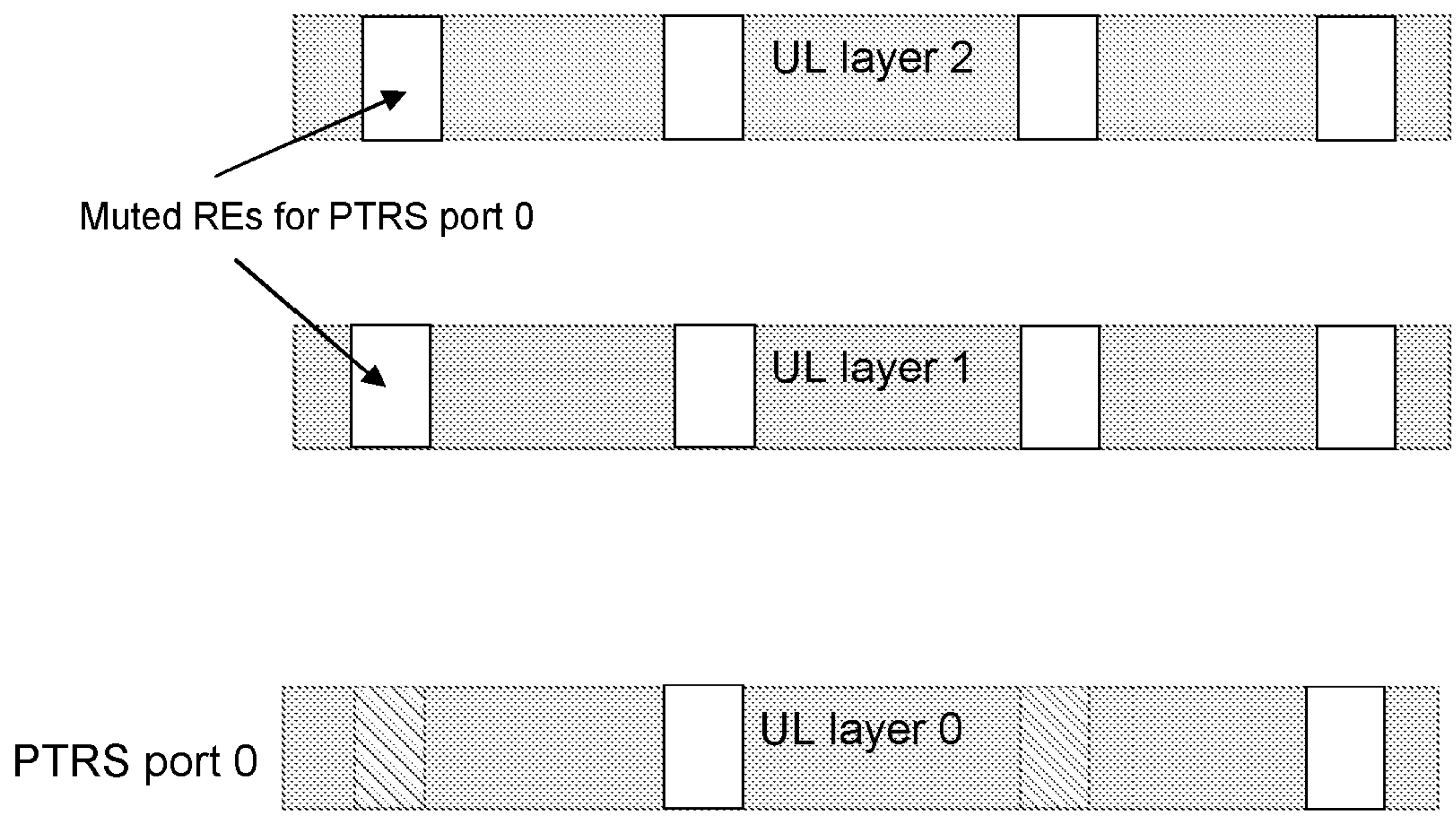

UL layer 2
Muted REs for PTRS port 0
UL layer 1
PTRS port 0
UL layer 0

Fig. 2

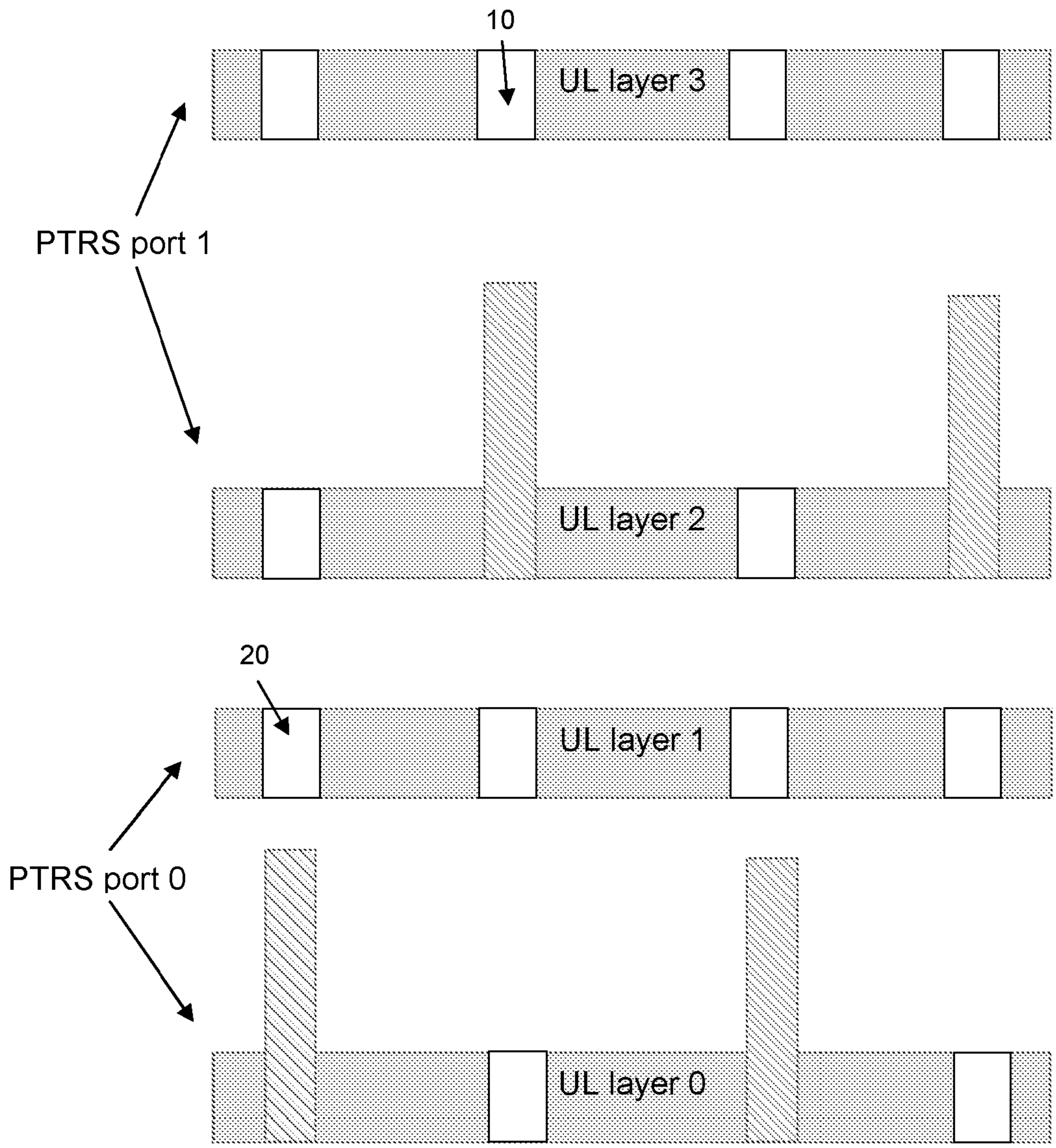

10
UL layer 3
PTRS port 1
UL layer 2
20
UL layer 1
PTRS port 0
UL layer 0

Fig. 3

Reference signal power boosting in a telecommunication system

The present invention relates to the boosting of certain reference signals in a telecommunication system. It relates particularly, but not exclusively to a Fifth Generation (5G) or New Radio (NR) system, although other systems may benefit. Further it relates particularly to the Phase Tracking Reference Signal (PTRS), although other reference signals may benefit. Further, it relates particularly to non-codebook-based uplink (UL) transmissions.

In NR systems, the power of the Phase Tracking Reference Signal (PTRS) may be boosted to improve common phase error (CPE) accuracy. Power boosting for PTRS in codebook-based UL transmission has been agreed in standardisation meetings and the agreement may be summarized by means of the following table (Table 1):

Table 1

UL-PTRS-power/	**Full coherent**				**Partial coherent**				**Non-coherent**			
	n_{layer}^{PUSCH}				n_{layer}^{PUSCH}				n_{layer}^{PUSCH}			
	1	2	3	4	1	2	3	4	1	2	3	4
00	0	3	4.77	6	0	Q	Q	Q+3	0	Q	Q	Q
01	0	3	4.77	6	0	3	4.77	6	0	3	4.77	6
10	reserved				reserved				reserved			
11	reserved				reserved				reserved			

Note that:

Q=0 for 1 PT-RS port case, Q=3 for 2 PT-RS port case.

If two PT-RS ports are configured, their Energy per Resource Element (EPREs) are the same.

However, for cases where non-codebook-based UL transmissions are made, then there is no agreed standardised approach. Embodiments of the present invention aim to address issues related to reference signal boosting in non-codebook-based UL transmissions.

According to the present invention there is provided an apparatus and method as set forth in the appended claims. Other features of the invention will be apparent from the dependent claims, and the description which follows.

Although a few preferred embodiments of the present invention have been shown and described, it will be appreciated by those skilled in the art that various changes and modifications might be made without departing from the scope of the invention, as defined in the appended claims.

For a better understanding of the invention, and to show how embodiments of the same may be carried into effect, reference will now be made, by way of example only, to the accompanying diagrammatic drawings in which:

Figure 1 shows a representation of PTRS power boosting for coherent UL transmission;

Figure 2 shows a representation of PTRS power boosting for partially coherent UL transmission; and

Figure 3 a representation of PTRS power boosting for non-codebook-based UL transmission.

For codebook-based UL transmissions, there may be a constraint on per antenna/antenna-port power constraint because the RF chain cost is higher without such a constraint and power boosting may be adjusted to include such a constraint.

For codebook-based (as opposed to non-codebook-based) UL transmission, it is known exactly whether the transmission is coherent, partially-coherent or non-coherent. For coherent transmission, there is only one RF chain and the power source is shared by all UL transmission layers.

Therefore, such a power constraint does not apply, as shown in Fig. 1, where single PTRS port 0 is boosted by 4 times (6dB), as shown by the enlarged shaded portions. On the contrary, for partial or non-coherent cases, there may be multiple RF chains and power sources. Fig. 1 illustrates a fully coherent scenario, with four UL layers. Each layer corresponds to a separate datastream, having its own DMRS port.

For instance, four UL transmission layers could be divided into multiple groups and each group has its own RF chain and power source so that any power sharing is only possible within each group. In such a case, power constraint applies and the power boosting can be performed based on the first row (00) of Table 1. This is illustrated in Fig. 2, where a single PTRS port is configured but its power is not boosted because of the per antenna/antenna-port power constraint.

Figure 2 illustrates a partially coherent scenario, where the shaded portions represent REs where PTRS is transmitted but power boosting is not permitted.

An issue for the current codebook-based UL transmission power boosting concerns the second row (01) of Table 1. For the first row (00), the number of PTRS ports can be configured as one or two. However, for the second row (01), there are some issues. In such a case, it should be configured such that the second row can only be configured when one PTRS port is configured, i.e., simultaneous configuration of 2 PTRS ports and UL-PTRS-power/ = “01” should be forbidden.

Embodiments of the invention address the power boosting problem for non-codebook based UL transmission. For non-codebook based transmission, the base station (gNB) may not be able to ascertain how precoding is performed by the UE and so therefore does not know if power constraints apply or not. In such a case, the worst case may be assumed, where there might be multiple power sources and they cannot be shared. The power boosting factor needs to be signaled via RRC.

In one embodiment, power can be borrowed from other UL layers where the corresponding DMRS ports share the same PTRS port.

When only one PTRS port is configured, power boosting may be based on the number of UL transmission layers, i.e., number of corresponding UL DMRS ports sharing the indicated UL PTRS port, which is essentially the same as is illustrated in Fig. 1.

When two PTRS ports are configured, there may be only one RF chain so that the power source can be shared. However, it is also possible that there are two RF chains, so that power sharing is not possible.

The gNB does not have such information. As mentioned above, the worst case needs to be considered in such a case, i.e., power sharing is not possible. As such, power boosting can be from two sources:

- Muted REs from another PTRS port
- Muted REs from other UL transmission layers where the corresponding UL DMRS ports share the same UL PTRS port

As shown in Fig. 3, two PTRS ports are configured. DMRS ports corresponding to UE layer 0 and 1 share PTRS port 0 and DMRS ports corresponding to UE layer 2 and 3 share PTRS port 1.

Both PTRS port 0 and 1 can be power boosted due to the muted REs configured for the other PTRS port i.e Port 0 can be boosted due to the muted REs configured for Port 1 and vice-versa.

In addition, it is possible to boost the power further due to the muted REs from another UE layer where the corresponding DMRS ports share the same PTRS port .

In Fig. 3, PTRS port 0 is power boosted by a factor of 2 (3dB), because of the muted REs for PTRS port 1 and is further boosted by a factor of 2 (3dB), giving a total of 6dB because of the muted REs (e.g. 20) for UL layer 1. The power boost is represented by the shaded taller bar.

Port 1 is power boosted by a factor of 2 (3dB), because of the muted REs for PTRS port 0 and is further boosted by a factor of 2 (3dB), giving a total of 6dB because of the muted REs (e.g.10) for UL layer 3. The power boost is represented by the shaded taller bar.

The power boosting $\rho_{PTRS,i}$ for PTRS port *i* can be expressed as

$$\rho_{PTRS,i} = -10\log_{10}(N_{PTRS}) - \alpha_{PTRS,i}$$

Where N_{PTRS} is the number of total PTRS ports, $\alpha_{PTRS,i}$ is shown in Table 2 below which is to be reflected in the standardisation protocols for NR.

Table 2

PUSCH-to-PT-RS EPRE ratio	**The number of PUSCH layers where the corresponding DMRS ports share the same PT-RS port *i*, (n_{layer}^{PUSCH})**			
	1	**2**	**3**	**4**
00	0	3	4.77	6
01	reserved			
10	reserved			
11	reserved			

It should be noted that one PTRS port can be associated with one Sounding Reference Signal - SRS port. One or multiple DMRS port(s) can be associated with the SRS port. In such a case, it is possible to use the number of DMRS ports associated with the SRS ports, where the PTRS port index associated with different Scheduling request indicator (SRIs) are the same. In such a case, n_{layer}^{PUSCH} can also be equal to the number of DMRS ports associated with the SRS ports, where the PTRS port index associated with different SRIs are the same.

In the case of coherence, table 2 can be modified to give Table 3, below:

Table 3

PUSCH-to-PT-RS EPRE ratio	**The number of PUSCH layers where the corresponding DMRS ports share the same PT-RS port *i*, ($n_{coherentlayer}^{PUSCH}$)**			
	1	**2**	**3**	**4**
00	0	3	4.77	6
01	reserved			
10	reserved			
11	reserved			

where $n_{coherentlayer}^{PUSCH}$ is the number of coherent PUSCH layers whose corresponding DMRS ports sharing the same PTRS port and it is equal to or smaller than n_{layer}^{PUSCH} .

In another embodiment, the power boosting factor $\rho_{PTRS,i}$ can be a fixed value so that

$$\rho_{PTRS,i} = -10\log_{10}(N_{PTRS})$$

if $\alpha_{PTRS,i}$ is set as 0.

Power boosting is then only decided by number of configured PTRS ports.

Alternatively, the following equation may apply:

$$\rho_{PTRS,i} = -10\log_{10}(N_{PTRS}) - \alpha_{PTRS,i}$$

This leads to Table 4, below:

Table 4

PUSCH-to-PT-RS EPRE ratio	**The number of PUSCH layers where the corresponding DMRS ports share the same PT-RS port *i*, (n_{layer}^{PUSCH})**			
	1	**2**	**3**	**4**
00	α	α	α	α
01	reserved			
10	reserved			
11	reserved			

where α can be any constant value.

For codebook-based transmission, a UE reports its UE capability as one of: 'partialAndNonCoherent '; 'Non-Coherent'; or ‘fullAndPartialAndNonCoherent’. For non-codebook-based transmission, according to an embodiment of the invention, this reporting information can also be used.

If the UE reports 'Non-Coherent' or does not report, it can be assumed that the UE can only work for non-coherent case and therefore, the power boosting factor can be shown to be:

$$\rho_{PTRS,i} = -10\log_{10}(N_{PTRS})$$

If the UE reports ‘fullAndPartialAndNonCoherent’, only one PTRS port can be configured, based on the agreement, and the power boosting factor is given as:

$$\rho_{PTRS,i} = -\alpha_{PTRS,i}$$

The following table, Table 5, then applies:

Table 5

PUSCH-to-PT-RS EPRE ratio	**The number of PUSCH layers where the corresponding DMRS ports share the same PT-RS port *i*, (n_{layer}^{PUSCH})**			
	1	**2**	**3**	**4**
00	0	3	4.77	6
01	reserved			
10	reserved			
11	reserved			

If the UE reports 'partialAndNonCoherent ', it can work either in non-coherent mode or partial-coherent mode. Table 6, below, then applies:

Table 6

UL-PTRS-power/	'partialAndNonCoherent ' reported			
	n_{layer}^{PUSCH}			
	1	2	3	4
00	0	$10\log_{10}(N_{PTRS})$	$10\log_{10}(N_{PTRS})$ + $10\log_{10}(n_{coherentlayer}^{PUSCH})$	$10\log_{10}(N_{PTRS})$ + $10\log_{10}(n_{coherentlayer}^{PUSCH})$
01	0	3	4.77	6
10	reserved			
11	reserved			

Here $n_{coherentlayer}^{PUSCH}$ is the number of coherent PUSCH layers whose corresponding DMRS ports share the same PTRS port.

The previous tables can be combined and represented by the following aggregate table, Table 7. This is similar to table 6.2.3.1-3 shown in 38.214 [NR; Physical layer procedures for data].

Table 7

UL-PTRS-power / α_{PTRS}^{PUSCH}	**The number of PUSCH layers (n_{layer}^{PUSCH})**								
	1	**2**		**3**			**4**		
	All cases	Full coherent	Partial and non-coherent	Full coherent	Partial coherent	non-coherent	Full coherent	Partial coherent	Non-coherent
00	0	3	$3Q_p$-3	4.77	$10\log_{10}(N_{PTRS})$ + $10\log_{10}(n_{coherentlayer}^{PUSCH})$	$3Q_p$-3	6	$10\log_{10}(N_{PTRS})$ + $10\log_{10}(n_{coherentlayer}^{PUSCH})$	$3Q_p$-3
01	0	3	3	4.77	4.77	4.77	6	6	6
10	Reserved								
11	Reserved								

where n_{layer}^{PUSCH} is The number of PUSCH layers where the corresponding DMRS ports share the same PT-RS port *i*, and $n_{coherentlayer}^{PUSCH}$ is the number of UL transmission layers which are coherent with each other and these UL layers contains the layer associated with the PTRS port.

In an alternative embodiment, the UE checks its own precoding matrix to identify the coherence of PUSCH layers. It then reports this to the gNB, which instructs the UE on the appropriate power boosting values based on table 6. Here, $n_{coherentlayer}^{PUSCH}$ can be estimated by the number of DMRS ports associated to the same SRS port.

Another approach to handle “partialAndNonCoherent” case is to assume non-coherent and thus power can only be borrowed from muted REs from another PTRS port. In such a case, the power boost factor can be represented as:

$$\rho_{PTRS,i} = -10\log_{10}(N_{PTRS}) .$$

This is reflected in the following table, Table 8

Table 8

UL-PTRS-power/	'partialAndNonCoherent' reported			
	n_{layer}^{PUSCH}			
	1	2	3	4
00	0	$10\log_{10}(N_{PTRS})$	$10\log_{10}(N_{PTRS})$	$10\log_{10}(N_{PTRS})$
01	0	3	4.77	6
10	reserved			
11	reserved			

In another embodiment, instead of the gNB deciding on the power boosting, the UE is operable to determine and configure it independently of the gNB. In particular, the gNB might not have all necessary information, e.g, $n_{coherentlayer}^{PUSCH}$. In such cases, power boosting can be decided by the UE based on its own precoding matrix, from which UE can identify $n_{coherentlayer}^{PUSCH}$.

It should be noted that some or all of the embodiments of the invention may violate the agreement in RAN1 (the Radio layer definition in NR) that symbols with and without PTRS should have the same power in UL. As such, there are two alternative solutions:

- Scale the power of the symbol with PTRS including PTRS and PUSCH to the same level as the symbol without PTRS, e.g., $\hat{\rho}_{PTRS,i} = \beta\rho_{PTRS,i}$, where β is the scaling factor.
- Scale up the power of the symbol without PTRS including PUSCH to the same level as the symbol with PTRS and PUSCH. This can be performed in the UE, as required.

A possible issue of power shortage may arise where the PTRS symbol power is attempted to be boosted to a level higher than the maximum power level that the UE can support. In such a case, it is preferable to reduce the power of PUSCH in the same antenna port and use this 'spare' power to provide the power for the PTRS power boosting.

The UE can decide to choose either power scaling or it may puncture PUSCH and use the power from PUSCH to provide the power for boosting PTRS.

It should also be noted that multiple different implementation may be supported by selectively merging one or more of the tables presented in this application.

Throughout this application, reference has been made to the PTRS reference signal, but it should be noted that the same principles apply to other reference signals - such as CSI-RS, DMRS, SRS and TRS - in the NR specification and that these other reference signals may also benefit from power boosting according to embodiments of the invention.

At least some of the example embodiments described herein may be constructed, partially or wholly, using dedicated special-purpose hardware. Terms such as 'component', 'module' or 'unit' used herein may include, but are not limited to, a hardware device, such as circuitry in the form of discrete or integrated components, a Field Programmable Gate Array (FPGA) or Application Specific Integrated Circuit (ASIC), which performs certain tasks or provides the associated functionality. In some embodiments, the described elements may be configured to reside on a tangible, persistent, addressable storage medium and may be configured to execute on one or more processors. These functional elements may in some embodiments include, by way of example, components, such as software components, object-oriented software components, class components and task components, processes, functions, attributes, procedures, subroutines, segments of program code, drivers, firmware, microcode, circuitry, data, databases, data structures, tables, arrays, and variables. Although the example embodiments have been described with reference to the components, modules and units discussed herein, such functional elements may be combined into fewer elements or separated into additional elements. Various combinations of optional features have been described herein, and it will be appreciated that described features may be combined in any suitable combination. In particular, the features of any one example embodiment may be combined with features of any other embodiment, as appropriate, except where such combinations are mutually exclusive. Throughout this specification, the term “comprising” or “comprises” means including the component(s) specified but not to the exclusion of the presence of others.

Attention is directed to all papers and documents which are filed concurrently with or previous to this specification in connection with this application and which are open to public inspection with this specification, and the contents of all such papers and documents are incorporated herein by reference.

All of the features disclosed in this specification (including any accompanying claims, abstract and drawings), and/or all of the steps of any method or process so disclosed, may be combined in any combination, except combinations where at least some of such features and/or steps are mutually exclusive.

Each feature disclosed in this specification (including any accompanying claims, abstract and drawings) may be replaced by alternative features serving the same, equivalent or similar purpose, unless expressly stated otherwise. Thus, unless expressly stated otherwise, each feature disclosed is one example only of a generic series of equivalent or similar features.

The invention is not restricted to the details of the foregoing embodiment(s). The invention extends to any novel one, or any novel combination, of the features disclosed in this specification (including any accompanying claims, abstract and drawings), or to any novel one, or any novel combination, of the steps of any method or process so disclosed.

CLAIMS

1. A method of boosting, in a user equipment, UE, the power of a phase tracking reference signal, PTRS, in an uplink non-codebook based transmission, wherein the power boosting is based on:

power borrowing from muted Resource Elements, REs, due to configuration of another reference signal port; or

power borrowing from muted Resource Elements, REs, due to configuration of another reference signal port and power borrowing between uplink transmission layers where corresponding Demodulation Reference Signal, DMRS, ports share the same phase tracking or sounding reference signal portwherein a power boosting factor $\rho_{PTRS,i}$ for PTRS port *i* can be expressed as

$$\rho_{PTRS,i} = -10\log_{10}(N_{PTRS}) - \alpha_{PTRS,i}$$

where N_{PTRS} = number of total PTRS ports, $\alpha_{PTRS,i}$ is shown in row 00 of the table below:

PUSCH-to-PT-RS EPRE ratio	**The number of PUSCH layers where the corresponding DMRS ports share the same PT-RS port *i*, (n_{layer}^{PUSCH})**			
	1	**2**	**3**	**4**
00	0	3	4.77	6
01	reserved			
10	reserved			
11	reserved			

2. The method according to claim 1, wherein the power boosting is based on power borrowing from muted REs due to configuration of another PTRS port and a fixed power boosting factor.

$$\rho_{PTRS,i} = -10\log_{10}(N_{PTRS}) - \alpha_{PTRS,i}$$

3. The method according to claim 1, wherein the power boosting is based on a UE capability report relating to support of coherent/partial-coherent/non-coherent precoding.

4. The method according to claim 3 wherein if the UE capability report indicates 'Non-Coherent' or does not report, the power boosting factor is:

$$\rho_{PTRS,i} = -10\log_{10}(N_{PTRS})$$

5. The method according to claim 3 wherein if the UE capability report indicates ‘fullAndPartialAndNonCoherent’, only one PTRS port is configured and the power boosting factor is:

$$\rho_{PTRS,i} = -\alpha_{PTRS,i}$$

And $\alpha_{PTRS,i}$ is shown in row 00 of the table below:

PUSCH-to-PT-RS EPRE ratio	**The number of PUSCH layers where the corresponding DMRS ports share the same PT-RS port *i*, (n_{layer}^{PUSCH})**			
	1	**2**	**3**	**4**
00	0	3	4.77	6
01	reserved			
10	reserved			
11	reserved			

6. The method according to claim 3 wherein if the UE capability report indicates 'partialAndNonCoherent' the UE can operate in either non-coherent mode or partial-coherent mode, and the following table applies:

UL-PTRS-power/	'partialAndNonCoherent' reported			
	n_{layer}^{PUSCH}			
	1	2	3	4
00	0	$10\log_{10}(N_{PTRS})$	$10\log_{10}(N_{PTRS})$	$10\log_{10}(N_{PTRS})$
01	0	3	4.77	6
10	reserved			
11	reserved			

where $n_{coherentlayer}^{PUSCH}$ is the number of coherent PUSCH layers whose corresponding DMRS ports share the same PTRS port.

7. The method according to claim 1, where the UE is operable to determine and configure power boosting independently of a base station, wherein the power boosting is determined based on the UE’s precoding matrix, from which the UE can identify $n_{coherentlayer}^{PUSCH}$.

8. The method according to any preceding claim, wherein power scaling is applied if a power shortage occurs.

9. The method according to any preceding claim wherein coherence information is derived by the UE and signalled to a base station or directly derived by the base station based on the association between SRS, UL DMRS and PTRS and configuration of SRI.

10. Apparatus arranged to perform the method of any preceding claim.

11. Apparatus as claimed in claim 10 wherein the apparatus is one or more of a user equipment or a base station.