REMARKS

The foregoing claim amendments are submitted prior to examination on the merits. The amendments cancel claims 1-38, and add new claims 39-70. New claims 39-70 are similar to selected ones of now canceled claims 1-38, but are written to eliminate multiple dependent claims, and to better comport the language of the claims with U.S. practice. No new matter has been added, and the amendments are not submitted for reasons related to patentability over any prior art.

Entry of the amendments is requested prior to examination on the merits.

Respectfully submitted,
COATS & BENNETT P.L.L.C.

Date: June 17, 2016

Justin J. Leonard
Registration No. 60,986
Telephone: (919) 854-1844

Replaces PTO/AIA/01 (06-12)

DECLARATION (37 CFR 1.63) FOR UTILITY OR DESIGN APPLICATION USING AN APPLICATION DATA SHEET (37 CFR 1.76)	Attorney Docket Number	P45698 WO1

Title of Invention	CODEBOOK SUBSET RESTRICTION SIGNALING

As the below named inventor, I hereby declare that:

This declaration is directed to:

☒ The attached application, or

☐ United States application or PCT international application number PCT/SE2016/050009, filed on January 11, 2016

The above-identified application was made or authorized to be made by me.

I believe that I am the original inventor or an original joint inventor of a claimed invention in the application.

I have reviewed and understand the contents of the above identified application, including the claims, as amended by any amendment specifically referred to above.

I am aware of the duty to disclose information which is material to patentability as defined in 37 CFR 1.56, including for continuation-in-part applications, material information which became available between the filing date of the prior application and the national or PCT international filing date of the continuation-in-part application.

I hereby acknowledge that any willful false statement made in this declaration is punishable under 18 U.S.C. 1001 by fine or imprisonment of not more than five (5) years, or both.

LEGAL NAME OF INVENTOR

Inventor: Niklas Wernersson Date (Optional):

Signature: 2016-02-15

Replaces PTO/AIA/01 (09-12)

DECLARATION (37 CFR 1.63) FOR UTILITY OR DESIGN APPLICATION USING AN APPLICATION DATA SHEET (37 CFR 1.76)	Attorney Docket Number	P45098 WO1

Title of Invention	CODEBOOK SUBSET RESTRICTION SIGNALING

As the below named inventor, I hereby declare that:

This declaration is directed to:

☐ The attached application, or

☒ United States application or PCT international application number PCT/SE2016/050009, filed on January 11, 2016

The above-identified application was made or authorized to be made by me.

I believe that I am the original inventor or an original joint inventor of a claimed invention in the application.

I have reviewed and understand the contents of the above identified application, including the claims, as amended by any amendment specifically referred to above.

I am aware of the duty to disclose information which is material to patentability as defined in 37 CFR 1.56, including for continuation-in-part applications, material information which became available between the filing date of the prior application and the national or PCT international filing date of the continuation-in-part application.

I hereby acknowledge that any willful false statement made in this declaration is punishable under 18 U.S.C. 1001 by fine or imprisonment of not more than five (5) years, or both.

LEGAL NAME OF INVENTOR

Inventor: Simon Järmyr Date (Optional):

Signature:

Replaces PTO/AIA/01 (05-12)

DECLARATION (37 CFR 1.63) FOR UTILITY OR DESIGN APPLICATION USING AN APPLICATION DATA SHEET (37 CFR 1.76)	Attorney Docket Number	P45698 WO1

Title of Invention	CODEBOOK SUBSET RESTRICTION SIGNALING

As the below named inventor, I hereby declare that:

This declaration is directed to:

- ☐ The attached application, or
- ☑ United States application or PCT international application number PCT/SE2016/050009, filed on January 11, 2016

The above-identified application was made or authorized to be made by me.

I believe that I am the original inventor or an original joint inventor of a claimed invention in the application.

I have reviewed and understand the contents of the above identified application, including the claims, as amended by any amendment specifically referred to above.

I am aware of the duty to disclose information which is material to patentability as defined in 37 CFR 1.56, including for continuation-in-part applications, material information which became available between the filing date of the prior application and the national or PCT international filing date of the continuation-in-part application.

I hereby acknowledge that any willful false statement made in this declaration is punishable under 18 U.S.C. 1001 by fine or imprisonment of not more than five (5) years, or both.

LEGAL NAME OF INVENTOR

Inventor: Sebastian Faxér

Date (Optional): 2016-01-25

Signature:

Replaces PTO/AIA/01 (09-12)

DECLARATION (37 CFR 1.63) FOR UTILITY OR DESIGN APPLICATION USING AN APPLICATION DATA SHEET (37 CFR 1.76)	Attorney Docket Number	P45699 WO1

Title of Invention	CODEBOOK SUBSET RESTRICTION SIGNALING

As the below named inventor, I hereby declare that:

This declaration is directed to:

☐ The attached application, or

☐ United States application or PCT international application number PCT/SE2016/050009, filed on January 11, 2016

The above-identified application was made or authorized to be made by me.

I believe that I am the original inventor or an original joint inventor of a claimed invention in the application.

I have reviewed and understand the contents of the above identified application, including the claims, as amended by any amendment specifically referred to above.

I am aware of the duty to disclose information which is material to patentability as defined in 37 CFR 1.56, including for continuation-in-part applications, material information which became available between the filing date of the prior application and the national or PCT international filing date of the continuation-in-part application.

I hereby acknowledge that any willful false statement made in this declaration is punishable under 18 U.S.C. 1001 by fine or imprisonment of not more than five (5) years, or both.

LEGAL NAME OF INVENTOR

Inventor: George Jöngren Date (Optional):

Signature:

Replaces PTO/AIA/01 (08-12)

DECLARATION (37 CFR 1.63) FOR UTILITY OR DESIGN APPLICATION USING AN APPLICATION DATA SHEET (37 CFR 1.76)	Attorney Docket Number	P45698 WO1

Title of Invention	CODEBOOK SUBSET RESTRICTION SIGNALING

As the below named inventor, I hereby declare that:

This declaration is directed to:

☐ The attached application, or

☐ United States application or PCT international application number PCT/SE2016/050009, filed on January 11, 2016

The above-identified application was made or authorized to be made by me.

I believe that I am the original inventor or an original joint inventor of a claimed invention in the application.

I have reviewed and understand the contents of the above identified application, including the claims, as amended by any amendment specifically referred to above.

I am aware of the duty to disclose information which is material to patentability as defined in 37 CFR 1.56, including for continuation-in-part applications, material information which became available between the filing date of the prior application and the national or PCT international filing date of the continuation-in-part application.

I hereby acknowledge that any willful false statement made in this declaration is punishable under 18 U.S.C. 1001 by fine or imprisonment of not more than five (5) years, or both.

LEGAL NAME OF INVENTOR

Inventor: Mattias Frenne Date (Optional):

Signature: 2016-01-25

POWER OF ATTORNEY

The undersigned, being duly authorized representatives of **TELEFONAKTIEBOLAGET LM ERICSSON (PUBL)** (hereafter referred to as "Ericsson") having its registered office as SE - 164 83 Stockholm, Sweden, does hereby authorize **Coats & Bennett, PLLC practitioners associated with United States Patent and Trademark Office Customer Number 24112** to represent Ericsson before the United States Patent and Trademark Office in any and all matters regarding patents or patent applications filed by Ericsson or wherein Ericsson is the assignee of the entire interest thereto.

This Power of Attorney shall include the right for **Coats & Bennett, PLLC practitioners associated with United States Patent and Trademark Office Customer Number 24112** to sign and submit in Ericsson's name and on Ericsson's behalf any document, notification, filing, petition or request in connection with any patent applications or patents owned by or assigned to Ericsson.

This Power of Attorney does not include the right to appoint substitutes or make sub-authorizations.

This Power of Attorney shall be valid for **five (5) years** from the date hereof unless earlier revoked. This Power of Attorney may be revoked at any time by Ericsson.

Stockholm, Sweden on

TELEFONAKTIEBOLAGET LM ERICSSON (PUBL)

Signature: _____ _____

Gabriele Mohsler — Vice President Patent Development

Nabil Ayoub — Director Patent Unit RAN2

Date: 2016-04-05

I, the undersigned, _____, Notary Public of the City of Stockholm hereby certify that _____ and _____

duly authorized to sign for

TELEFONAKTIEBOLAGET LM ERICSSON (PUBL)

have issued and signed the foregoing document

Fee **Stockholm [Date]**

Crowns **Ex officio:**

_____

Signature: Notary Public of the City of Stockholm

PTO/AIA/96 (08-12)
Approved for use through 01/31/2013. OMB 0651-0031
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE

STATEMENT UNDER 37 CFR 3.73(c)

Applicant/Patent Owner: Telefonaktiebolaget LM Ericsson (publ)

Application No./Patent No.: TBA Filed/Issue Date: TBA

Titled: Codebook Subset Restriction Signaling

Telefonaktiebolaget LM Ericsson (publ), a corporation

(Name of Assignee) (Type of Assignee, e.g., corporation, partnership, university, government agency, etc.)

states that, for the patent application/patent identified above, it is (choose **one** of options 1, 2, 3 or 4 below):

1. ☑ The assignee of the entire right, title, and interest.

2. ☐ An assignee of less than the entire right, title, and interest (check applicable box):

   ☐ The extent (by percentage) of its ownership interest is _____%. Additional Statement(s) by the owners holding the balance of the interest must be submitted to account for 100% of the ownership interest.

   ☐ There are unspecified percentages of ownership. The other parties, including inventors, who together own the entire right, title and interest are:

   Additional Statement(s) by the owner(s) holding the balance of the interest must be submitted to account for the entire right, title, and interest.

3. ☐ The assignee of an undivided interest in the entirety (a complete assignment from one of the joint inventors was made). The other parties, including inventors, who together own the entire right, title, and interest are:

   Additional Statement(s) by the owner(s) holding the balance of the interest must be submitted to account for the entire right, title, and interest.

4. ☐ The recipient, via a court proceeding or the like (*e.g.*, bankruptcy, probate), of an undivided interest in the entirety (a complete transfer of ownership interest was made). The certified document(s) showing the transfer is attached.

The interest identified in option 1, 2 or 3 above (not option 4) is evidenced by either (choose **one** of options A or B below):

A. ☑ An assignment from the inventor(s) of the patent application/patent identified above. The assignment was recorded in the United States Patent and Trademark Office at Reel _____, Frame _____, or for which a copy thereof is attached.

B. ☐ A chain of title from the inventor(s), of the patent application/patent identified above, to the current assignee as follows:

1. From: _____ To: _____

   The document was recorded in the United States Patent and Trademark Office at

   Reel _____, Frame _____, or for which a copy thereof is attached.

2. From: _____ To: _____

   The document was recorded in the United States Patent and Trademark Office at

   Reel _____, Frame _____, or for which a copy thereof is attached.

PTO/AIA/96 (08-12)
Approved for use through 01/31/2013. OMB 0651-0031
U.S. Patent and Trademark Office: U.S. DEPARTMENT OF COMMERCE

STATEMENT UNDER 37 CFR 3.73(c)

3. From: _____ To: _____

The document was recorded in the United States Patent and Trademark Office at

Reel _____, Frame _____, or for which a copy thereof is attached.

4. From: _____ To: _____

The document was recorded in the United States Patent and Trademark Office at

Reel _____, Frame _____, or for which a copy thereof is attached.

5. From: _____ To: _____

The document was recorded in the United States Patent and Trademark Office at

Reel _____, Frame _____, or for which a copy thereof is attached.

6. From: _____ To: _____

The document was recorded in the United States Patent and Trademark Office at

Reel _____, Frame _____, or for which a copy thereof is attached.

☐ Additional documents in the chain of title are listed on a supplemental sheet(s).

☑ As required by 37 CFR 3.73(c)(1)(i), the documentary evidence of the chain of title from the original owner to the assignee was, or concurrently is being, submitted for recordation pursuant to 37 CFR 3.11.

[NOTE: A separate copy (i.e., a true copy of the original assignment document(s)) must be submitted to Assignment Division in accordance with 37 CFR Part 3, to record the assignment in the records of the USPTO. See MPEP 302.08]

The undersigned (whose title is supplied below) is authorized to act on behalf of the assignee.

/ Justin J. Leonard /	2016-06-17
Signature	Date
Justin J. Leonard	60986
Printed or Typed Name	Title or Registration Number

Privacy Act Statement

The **Privacy Act of 1974 (P.L. 93-579)** requires that you be given certain information in connection with your submission of the attached form related to a patent application or patent. Accordingly, pursuant to the requirements of the Act, please be advised that: (1) the general authority for the collection of this information is 35 U.S.C. 2(b)(2); (2) furnishing of the information solicited is voluntary; and (3) the principal purpose for which the information is used by the U.S. Patent and Trademark Office is to process and/or examine your submission related to a patent application or patent. If you do not furnish the requested information, the U.S. Patent and Trademark Office may not be able to process and/or examine your submission, which may result in termination of proceedings or abandonment of the application or expiration of the patent.

The information provided by you in this form will be subject to the following routine uses:

1. The information on this form will be treated confidentially to the extent allowed under the Freedom of Information Act (5 U.S.C. 552) and the Privacy Act (5 U.S.C 552a). Records from this system of records may be disclosed to the Department of Justice to determine whether disclosure of these records is required by the Freedom of Information Act.
2. A record from this system of records may be disclosed, as a routine use, in the course of presenting evidence to a court, magistrate, or administrative tribunal, including disclosures to opposing counsel in the course of settlement negotiations.
3. A record in this system of records may be disclosed, as a routine use, to a Member of Congress submitting a request involving an individual, to whom the record pertains, when the individual has requested assistance from the Member with respect to the subject matter of the record.
4. A record in this system of records may be disclosed, as a routine use, to a contractor of the Agency having need for the information in order to perform a contract. Recipients of information shall be required to comply with the requirements of the Privacy Act of 1974, as amended, pursuant to 5 U.S.C. 552a(m).
5. A record related to an International Application filed under the Patent Cooperation Treaty in this system of records may be disclosed, as a routine use, to the International Bureau of the World Intellectual Property Organization, pursuant to the Patent Cooperation Treaty.
6. A record in this system of records may be disclosed, as a routine use, to another federal agency for purposes of National Security review (35 U.S.C. 181) and for review pursuant to the Atomic Energy Act (42 U.S.C. 218(c)).
7. A record from this system of records may be disclosed, as a routine use, to the Administrator, General Services, or his/her designee, during an inspection of records conducted by GSA as part of that agency's responsibility to recommend improvements in records management practices and programs, under authority of 44 U.S.C. 2904 and 2906. Such disclosure shall be made in accordance with the GSA regulations governing inspection of records for this purpose, and any other relevant (*i.e.*, GSA or Commerce) directive. Such disclosure shall not be used to make determinations about individuals.
8. A record from this system of records may be disclosed, as a routine use, to the public after either publication of the application pursuant to 35 U.S.C. 122(b) or issuance of a patent pursuant to 35 U.S.C. 151. Further, a record may be disclosed, subject to the limitations of 37 CFR 1.14, as a routine use, to the public if the record was filed in an application which became abandoned or in which the proceedings were terminated and which application is referenced by either a published application, an application open to public inspection or an issued patent.
9. A record from this system of records may be disclosed, as a routine use, to a Federal, State, or local law enforcement agency, if the USPTO becomes aware of a violation or potential violation of law or regulation.

ASSIGNMENT

This Assignment is made by:

FAXÉR, Sebastian	**Barkarbyvägen 53 D SE-177 44 JÄRFÄLLA Sweden**
FRENNE, Mattias	**Arkeologvägen 20 SE-754 43 UPPSALA Sweden**
JÄRMYR, Simon	**Luftfartsgatan 8 SE-128 34 SKARPNÄCK Sweden**
JÖNGREN, George	**Kronogårdsvägen 44 SE-174 62 SUNDBYBERG Sweden**
WERNERSSON, Niklas	**Tunvägen 14 SE-170 68 SOLNA Sweden**

(hereinafter referred to as "Assignor(s)") in favor, and for the benefit and behoof of, Telefonaktiebolaget LM Ericsson (publ), a corporation duly organized under and pursuant to the laws of Sweden and having its principal place of business at SE-164 83 Stockholm, Sweden (hereinafter referred to as "Assignee").

For good, sufficient and adequate consideration, the receipt of which is hereby acknowledged, the Assignor(s) have, as of the Effective Date, sold, assigned, transferred, and set over, and by these presents, and to the extent any transferable or assignable rights still remain with the inventor, do hereby sell, assign, transfer, and set over, unto the Assignee, its successors, legal representatives, and assigns the entire right, title, and interest in and to the following inventions, application(s) for Letters Patent, and any and all Letters Patent or Patents in all countries and pursuant to all multilateral treaty organizations, including Sweden, the United States of America, the Patent Cooperation Treaty and European Patent Convention, that may be granted therefor and thereon, and in and to any and all divisions, continuations, continuations-in-part, conversions and utility models of said application(s), and reissues and extensions of said Letters Patent or Patents, the same to be held and enjoyed by the Assignee, for its use and behoof and the use and the behoof of its successors, legal representatives, and assigns, to the full end of the term or terms for which Letters Patent, Patents and Utility Models may be granted as fully and entirely as the same would have been held and enjoyed by the Assignor(s) had this sale and assignment not been made:

CODEBOOK SUBSET RESTRICTION SIGNALING

ASSIGNMENT

including, but not limited to, the application(s) for Letters Patent and Utility Model filed in:

Country Code	Priority Application(s)	Filing Date(s)
WO	PCT/SE2016/050009	2016-01-11
		- -

The Effective date is the earliest date of the above listed Filing Date(s).

Assignor(s) hereby authorize and request Assignee's Attorneys to insert the serial number and filing date of said application(s) for Letter Patent or Utility Model, when known. The assignment of the above mentioned rights includes a transfer of the whole right to use a priority (including priority according to any convention, multilateral agreement, bilateral agreement and national law) of the above mentioned application(s) for Letter Patent and Utility Model in all countries and multilateral treaty organizations wherein no residual rights shall remain with the Assignor(s). Assignor(s) hereby request that said Letters Patent, Patent or Utility Model be issued to Assignee as the Assignee of said inventions, the Letters Patent, Patent or Utility Model to be issued for the sole use and behoof of the Assignee, its successors, legal representatives, and assigns. Assignee alone hereinafter has the entire disposal of the invention and possesses entire ownership to any domestic and foreign patents or utility models granted thereinafter. The rights granted hereunder shall include all rights to institute legal actions, obtain remedies and recover and retain damages in respect to said Letters Patent, Patent or Utility Model.

The Assignor(s) and Assignee hereby understand and agree that with the execution of this Assignment, to the extent necessary or appropriate, national and/or regional applications may be filed by the Assignee as the applicant and on behalf of the assignor.

To the extent Assignee is entitled to receive the rights hereunder pursuant to this Assignment, each of the Assignor(s) hereby covenants and agrees to and with the Assignee, its successors, legal representatives, and assigns, that, at the time of the Effective Date, the Assignor(s) were the sole and lawful owners of the entire right, title, and interest in and to the inventions and application(s) for Letters Patent or Utility Models above-mentioned, and that the same are unencumbered, and that the Assignor(s) have good and full right and lawful authority to sell and convey the same in the manner herein set forth.

Further, and for the same consideration, the Assignor(s) hereby covenant(s) and agree(s) to and with the Assignee, its successors, legal representatives, and assigns that the Assignor(s) will, whenever counsel of the Assignee, or the counsel of its successors, legal representatives, and assigns, shall advise that any proceeding in connection with said inventions or said application(s) for Letters Patent or Utility Model, or any proceeding in connection with Letters Patent or Utility Model for said inventions, in any country and any multilateral treaty organization, including interference proceedings, is lawful and desirable, or that any division, continuation, continuation-in-part, conversion or Utility Model of any application(s) for Letters Patent or Utility Model, or any reissue or extension of any Letters Patent to be obtained thereon, is lawful and desirable, sign all papers and documents, take all lawful oaths, and do all acts necessary or required to be done for the procurement, maintenance, enforcement, and defense of Letters Patent or Utility Model for said inventions, without charge to Assignee, its successors, legal representatives, and

ASSIGNMENT

assigns, but at the cost and expense of the Assignee, its successors, legal representatives, and assigns. If any of the Assignor(s) is prevented by any obstacles from signing said documents in person, this Assignment shall be valid as a Power of Attorney for the Assignee to sign these documents on behalf of any such Assignor(s) or, in the event of the death of the latter, the estate thereof.

This Assignment shall be governed by and construed under, and any dispute, controversy or claim related hereto shall be decided in accordance with, the laws of:
Sweden

without regard to the conflicts of laws provisions thereof. Any dispute, controversy or claim arising under, out of or relating to this Assignment and any subsequent amendments of this Assignment, including, without limitation, its formation, validity, binding effect, interpretation, performance, breach or termination, as well as non-contractual claims, shall be referred to and finally determined by arbitration in accordance with the WIPO Arbitration Rules. The arbitral tribunal shall consist of a sole arbitrator. The place of arbitration shall be in the country of the inventor's residence. The language to be used in the arbitral proceedings shall be English.

No modifications shall be made to this Assignment unless in writing and signed by each of the Assignor(s) and Assignee. If any of the provisions of this Assignment shall be deemed invalid or unenforceable, then the entire Assignment shall be construed as if not containing the particular invalid or unenforceable provision or provisions, and the rights and obligations of Assignee and Assignor(s) shall be construed and enforced accordingly. Assignee's failure to exercise any option made available as a result hereof, shall not be construed as a waiver of such provisions, rights, or options, or affect the validity of this Assignment. Assignor covenants and agrees that it will not take any actions in violation of this Assignment.

Subsequent assignment from any of the assignors to the assignee purporting to convey the subject matter specified herein for a particular country, patent office, or jurisdiction shall not invalidate any provision of this assignment and any such subsequent assignment shall act as a further confirmation of the assignment herein.

Date 2016-06-07 Signature on behalf of Assignee  Roger Bou Faical

ASSIGNMENT

Title: CODEBOOK SUBSET RESTRICTION SIGNALING

Date 2016-01-25 Signature of Assignor

FAXÉR, Sebastian

Date 2016-01-25 Witnessed by

Name: Erik Dahlman

Address: Schedegatan 3
12233 Stockholm

Date 2016-01-25 Witnessed by

Name: Svante Bergman

Address: Selmedalsvägen 8
12936 Hägersten
Sweden

ASSIGNMENT

Title: CODEBOOK SUBSET RESTRICTION SIGNALING

Date 2016-01-25 Signature of Assignor

FRENNE, Mattias

Date 2016-01-25 Witnessed by

Name: Håkan Persson

Address: Krysshammar 22
171 52 SOLNA
SWEDEN

Date 2016-01-25 Witnessed by

Name: Lars Lindbom

Address: Fossegatan 7
652 62 Karlstad
SWEDEN

ASSIGNMENT

Title: CODEBOOK SUBSET RESTRICTION SIGNALING

Date 2016-01-25 Signature of Assignor JARMYR, Simon

Date 2016-01-25 Witnessed by

Name: Maksym Girnyk

Address: Professorsbingen 37
11417 Stockholm
Sweden

Date 2016-01-25 Witnessed by

Name: Richard Abrahamsson

Address: Åsögatan 45
741 45 KNIVSTA
SWEDEN

ASSIGNMENT

Title: CODEBOOK SUBSET RESTRICTION SIGNALING

Date 2016-05-23 Signature of Assignor

JÖNGREN, George

Date 2016-05-23 Witnessed by

Name: MAKSYM GIRNYK

Address: Professorsslingan 37
114 17 Stockholm
Sweden

Date 2016-05-23 Witnessed by

Name: Hazhir Shokri Razghi

Address: Hantavägen 49 lgh 1653
16543 Kista
Sweden

ASSIGNMENT

Title: CODEBOOK SUBSET RESTRICTION SIGNALING

Date 2016-02-15 Signature of Assignor

WERNERSSON, Niklas

Date 2016-02-15 Witnessed by

Name: BARBARA REGAL

Address: TUVV. 14

11068 SOLNA

SWEDEN

Date 2016-02-15 Witnessed by

Name: Diana Caraghiaur

Address: Tunvägen 14

11068 Solna

Sweden

Doc code: IDS
Doc description: Information Disclosure Statement (IDS) Filed

PTO/SB/08a (03-15)
Approved for use through 07/31/2016. OMB 0651-0031
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
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INFORMATION DISCLOSURE STATEMENT BY APPLICANT
(Not for submission under 37 CFR 1.99)

Application Number	
Filing Date	
First Named Inventor	Faxér
Art Unit	
Examiner Name	
Attorney Docket Number	4015-9595 / P45698-US2

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Examiner Initial*	Cite No	Publication Number	Kind Code[1]	Publication Date	Name of Patentee or Applicant of cited Document	Pages,Columns,Lines where Relevant Passages or Relevant Figures Appear
	1	20110243098	A1	2011-11-06	Koivisto et al.	
	2	20130163687	A1	2013-06-27	Jing et al.	

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INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)		
	Application Number	
	Filing Date	
	First Named Inventor	Faxér
	Art Unit	
	Examiner Name	
	Attorney Docket Number	4015-9595 / P45698-US2

Examiner Initials*	Cite No	Include name of the author (in CAPITAL LETTERS), title of the article (when appropriate), title of the item (book, magazine, journal, serial, symposium, catalog, etc), date, pages(s), volume-issue number(s), publisher, city and/or country where published.	T[5]
	1	ERICSSON, "Remaining Details of Codebook Subset Restriction", 3GPP TSG-RAN WG1#83, Anaheim, USA, 2015-11-15, pp. 1-6, R1-157203, 3GPP	
	2	AT&T, "WF on class A and class B CSI reporting for Rel.13 EB FD-MIMO", 3GPP TSG RAN WG1 Meeting #82bis, Malmö, Sweden, 2015-10-05, pp. 1-10, R1-156165, 3GPP	

If you wish to add additional non-patent literature document citation information please click the Add button Add

EXAMINER SIGNATURE

Examiner Signature		Date Considered	

*EXAMINER: Initial if reference considered, whether or not citation is in conformance with MPEP 609. Draw line through a citation if not in conformance and not considered. Include copy of this form with next communication to applicant.

[1] See Kind Codes of USPTO Patent Documents at www.USPTO.GOV or MPEP 901.04. [2] Enter office that issued the document, by the two-letter code (WIPO Standard ST.3). [3] For Japanese patent documents, the indication of the year of the reign of the Emperor must precede the serial number of the patent document. [4] Kind of document by the appropriate symbols as indicated on the document under WIPO Standard ST.16 if possible. [5] Applicant is to place a check mark here if English language translation is attached.

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)		
	Application Number	
	Filing Date	
	First Named Inventor	Faxér
	Art Unit	
	Examiner Name	
	Attorney Docket Number	4015-9595 / P45698-US2

CERTIFICATION STATEMENT

Please see 37 CFR 1.97 and 1.98 to make the appropriate selection(s):

That each item of information contained in the information disclosure statement was first cited in any communication from a foreign patent office in a counterpart foreign application not more than three months prior to the filing of the information disclosure statement. See 37 CFR 1.97(e)(1).

OR

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See attached certification statement.

The fee set forth in 37 CFR 1.17 (p) has been submitted herewith.

☒ A certification statement is not submitted herewith.

SIGNATURE

A signature of the applicant or representative is required in accordance with CFR 1.33, 10.18. Please see CFR 1.4(d) for the form of the signature.

Signature	/ Justin J. Leonard /	Date (YYYY-MM-DD)	2016-06-17
Name/Print	Justin J. Leonard	Registration Number	60986

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3GPP TSG RAN WG1 Meeting #82bis **R1-156165**
Malmö, Sweden, 5th - 9th October 2015

AI: 7.2.4.3

WF on class A and class B CSI reporting for Rel.13 EB/FD-MIMO

AT&T, Beijing Xinwei Telecom Tech., CATR, CATT, CHTTL, CMCC, Deutsche Telekom, Ericsson, ETRI, Huawei, HiSilicon, ITRI, Kathrein-Werke KG, KDDI, KT Corporation, Nokia Networks, NTT DOCOMO, Samsung, Sony Corporation

Background:
Class A codebook structure (R1-154861)

- For each of [8], 12 and 16 Tx ports, a precoding matrix $\boldsymbol{W}$ in the codebook is represented as:

$$\boldsymbol{W} = \boldsymbol{W}_1 \boldsymbol{W}_2$$

where:

  - $\boldsymbol{W}_1 = \begin{pmatrix} \boldsymbol{X}_1 \otimes \boldsymbol{X}_2 & 0 \\ 0 & \boldsymbol{X}_1 \otimes \boldsymbol{X}_2 \end{pmatrix}$, $\boldsymbol{W}_2$ FFS
  - $\boldsymbol{X}_1$ is a $N_1 x L_1$ matrix with L_1 column vectors being an O_1x oversampled DFT vector of length N_1: $\boldsymbol{v}_l = \left[1 \quad e^{\frac{j2\pi l}{N_1 O_1}} \quad \ldots \quad e^{\frac{j2\pi (N_1-1) l}{N_1 O_1}}\right]^t$
  - $\boldsymbol{X}_2$ is a $N_2 x L_2$ matrix with L_2 column vectors being an O_2x oversampled DFT vector of length N_2: $\boldsymbol{v}_l = \left[1 \quad e^{\frac{j2\pi l}{N_2 O_2}} \quad \ldots \quad e^{\frac{j2\pi (N_2-1) l}{N_2 O_2}}\right]^t$
  - N_1 and N_2 are the numbers of antenna ports per pol in 1st and 2nd dim.
  - FFS whether to select different beams (e.g. different X_1 or X_2) for the two pols
  - FFS column selection from KP applied to W_1

Class A proposal

- Rel.13 class A codebook configured with 5 RRC parameters:
  - N_1, N_2 = {1,2,3,4,8} where the valid candidates are (N_1, N_2) = (8,1), (2,2), (2,3), (3,2), (2,4), (4,2)
  - O_1, O_2 = {2,4,8}
    - For each (N_1, N_2), configurability of (O_1, O_2) is restricted to two possible fixed pairs
    - Exact values TBD by Fri, 10/09/2015
  - *Config* = {1, 2, 3, 4}
  - Note: For dimension with one port, oversampling factor and *Config* = {2, 3} do not apply
- Given the set of values of N_1,N_2,O_1,O_2:
  - $\mathbf{W}_1$ matrices with (L'_1,L'_2) = (4,2), (2,4) are constructed for N_1>N_2 and N_1<N_2, respectively
  - $\boldsymbol{W}_1 = \begin{pmatrix} \boldsymbol{X}_1^{m_1} \otimes \boldsymbol{X}_2^{m_2} & 0 \\ 0 & \boldsymbol{X}_1^{m_1} \otimes \boldsymbol{X}_2^{m_2} \end{pmatrix}$ where m_i is the index for $\boldsymbol{X}_i$
  - An associated codebook table is defined in terms of i'_2, i_{11} and i_{12} (refer to slide 5)
- Given the value of *Config*, a subset of codewords from the codebook table is selected as an active subset of values of i'_2, associated with one of the following 4 configurations: (see slide 5)
  - Config =1: (L_1,L_2) = (1,1) for rank 1-2
  - Config =2: (L_1,L_2) = (2,2) for rank 1-2 [square]
  - Config =3: (L_1,L_2) = (2,2) for rank 1-2 [non-adjacent 2D beams/checkerboard]
  - Config =4: (L_1,L_2) = (4,1), (1,4) for N_1>N_2 and N_1<N_2 respectively for rank 1-2
  - TBD rank 3-8

Class A proposal

- One selected value out of the active subset is reported by the second PMI i_2 in PUSCH reporting.

- Note: Configs 1-4 require the following $\mathbf{W}_1$ matrix construction:
  - $\boldsymbol{X}_1^{m_1} \otimes \boldsymbol{X}_2^{m_2}$ will have either 1 or 4 columns dependent upon the configuration:
    - *Config* = 1 : 1 column
    - *Config* = 2, 3, 4 : 4 columns

- The PMI feedback payload is adjusted based on *Config*
  - *Config* = 1 (compact i_2, no beam selection for 1 and 2 layers):
    - # of bits for i_{11} and i_{12} = ceil($\log_2(N_1O_1)$) + ceil($\log_2(N_2O_2)$)
    - # of bits for i_2 (per rank 1,2) = (2,2)
  - *Config* = 2, 3, 4 (following legacy):
    - # of bits for i_{11} and i_{12} = ceil($\log_2(N_1O_1/2)$)+ ceil($\log_2(N_2O_2/2)$)
    - # of bits for i_2 (per rank 1,2) = (4,4)
  - TBD rank 3-8

Class A: rank-1 CB

- The codebook is defined by the table below (with 32 CWs, $(L'_1, L'_2) = (4, 2)$). UE selects 4 or 16 CWs for the second PMI i_2 to be reported on PUSCH, based on *Config*.

i'_2	0	1	2	3
Precoder	$W^{(1)}_{s_1 i_{1,1}, s_2 i_{1,2}, 0}$	$W^{(1)}_{s_1 i_{1,1}, s_2 i_{1,2}, 1}$	$W^{(1)}_{s_1 i_{1,1}, s_2 i_{1,2}, 2}$	$W^{(1)}_{s_1 i_{1,1}, s_2 i_{1,2}, 3}$
i'_2	4	5	6	7
Precoder	$W^{(1)}_{s_1 i_{1,1}+1, s_2 i_{1,2}, 0}$	$W^{(1)}_{s_1 i_{1,1}+1, s_2 i_{1,2}, 1}$	$W^{(1)}_{s_1 i_{1,1}+1, s_2 i_{1,2}, 2}$	$W^{(1)}_{s_1 i_{1,1}+1, s_2 i_{1,2}, 3}$
i'_2	8	9	10	11
Precoder	$W^{(1)}_{s_1 i_{1,1}+2, s_2 i_{1,2}, 0}$	$W^{(1)}_{s_1 i_{1,1}+2, s_2 i_{1,2}, 1}$	$W^{(1)}_{s_1 i_{1,1}+2, s_2 i_{1,2}, 2}$	$W^{(1)}_{s_1 i_{1,1}+2, s_2 i_{1,2}, 3}$
i'_2	12	13	14	15
Precoder	$W^{(1)}_{s_1 i_{1,1}+3, s_2 i_{1,2}, 0}$	$W^{(1)}_{s_1 i_{1,1}+3, s_2 i_{1,2}, 1}$	$W^{(1)}_{s_1 i_{1,1}+3, s_2 i_{1,2}, 2}$	$W^{(1)}_{s_1 i_{1,1}+3, s_2 i_{1,2}, 3}$
i'_2	16 – 31			
Precoder	Entries 16-31 constructed with replacing the second subscript $s_2 i_{1,2}$ with $s_2 i_{1,2}+1$ in entries 0 – 15			

Config	Selected i'$_2$ indices	(s_1, s_2)
Config 1	0 – 3	(1,1)
Config 2	0 – 7, 16 – 23	(2,2)
Config 3	0-3, 8-11, 20-23, 28-31	(2,2)
Config 4	0 – 15	(2,2)

Oversampling factors o_d
Beam group spacing: s_d
First PMI: $i_{1,d}$

$$W^{(1)}_{m_1,m_2,n} = \frac{1}{\sqrt{Q}} \begin{bmatrix} v_{m_1} \otimes u_{m_2} \\ \varphi_n v_{m_1} \otimes u_{m_2} \end{bmatrix}$$

$$v_{m_1} = \begin{bmatrix} 1 & e^{j\frac{2\pi m_1}{o_1 N_1}} & \cdots & e^{j\frac{2\pi m_1 (N_1-1)}{o_1 N_1}} \end{bmatrix}^T$$

$$u_{m_2} = \begin{bmatrix} 1 & e^{j\frac{2\pi m_2}{o_2 N_2}} & \cdots & e^{j\frac{2\pi m_2 (N_2-1)}{o_2 N_2}} \end{bmatrix}^T$$

Codebook Subset Restriction

- Note: A 2D-beam corresponds to (l_1, l_2) in $\boldsymbol{X}_1 \otimes \boldsymbol{X}_2$
- Codebook subset restriction (CSR) is supported for FD-MIMO
  - CSR is configured via RRC signaling
  - A subset of 2D-beams (l_1, l_2) are forbidden, i.e. not allowed to be reported according to the CSR configuration
    - A forbidden 2D-beam is not allowed in reporting with any rank
  - Rank restriction is also supported
  - Number of PMI bits does not vary according to restricted subset
    - Note: Codebook subset restriction targets e.g. performance/capacity, as in Rel-8 to Rel-12

Background: Class B alternatives (RAN1#82)

- Study the following aspects for CSI-process reporting class B, including but not limited to
  - Number of antenna ports *L* for CSI (e.g., 2, 4, 8)
  - Class B Alt-1:
    - Beam selection indicator (BI) definition, e.g. RSRP or CSI based, wideband vs. subband, short-term vs. long-term
    - BI bitwidth (related to K)
    - Support for rank>2 UE specific beamforming
    - UCI feedback mechanisms on PUCCH/PUSCH
  - Class B Alt-2:
    - Codebook for beam selection and co-phasing (either derived from legacy codebook(s) or codebook components, or newly designed)
      - Along with the associated PMI (e.g. assuming W = W2 in the newly designed or legacy codebook)
    - UCI feedback mechanisms on PUCCH/PUSCH
  - Class B Alt-3:
    - Codebook for beam selection and CSI
      - PMI contains the information of selected beam and the precoding matrix for the L-port within the selected beam
    - UCI feedback mechanisms on PUCCH/PUSCH
  - Class B Alt-4:
    - Measurement restriction mechanism; may be also applicable to Alt-1 to 3.
- Other aspects not precluded

Class B proposal

- Value K is configured to the UE where K≥1, representing K beams
  - K={1, 2, ..., 8} conditioned upon $N_1+...+N_K \leq N_{TOTAL}$
  - N_{TOTAL} is TBD
- For K>1
  - For each of the K beams, a value N_k={1, 2, 4, 8} is configured as one Rel.12 NZP CSI-RS resource
  - BI feedback is included in CSI report to select one out of K beams
  - For the selected beam k=k', CSI reporting based on legacy codebook for $N_{k'}$ ports
- One CSI process can be configured with multiple CSI-IM
  - Different CSI-RS resource can be associated with different CSI-IM

Class B proposal

- For K=1
  - A value N_1={1, 2, 4, 8} is configured as one Rel.12 NZP CSI-RS resource
    - eNodeB signals the number of ports N_1 via NZP CSI-RS resource configuration
  - CSI reporting with PMI-feedback-only based on W_2-only feedback for N_1 ports
    - Using all/components of W_2 in Rel.13 class A codebook configuration 4 (see slide 3)
      - DFT vectors are replaced by column vectors of identity matrix
  - In addition, legacy (Rel.12) CSI reporting is also supported with MR functionality

- For K=1, a new N_1-port codebook (where each different CSI-RS port is virtualized from different sets of antenna elements) is to be investigated and possibly specified in Rel.14

Other features

- MR (measurement restriction) is an independent feature (configurable ON/OFF)
  - For both channel and interference

- The maximum number X of CSI-IM is defined per UE across the maximum supported CSI processes.
  - X is the same for Class A and B
  - For Class A,
    - One CSI-IM per CSI process
    - Implies an increase in the max number of supported CSI processes if X>3
  - For Class B,
    - Multiple CSI-IM per CSI process is possible

3GPP TSG-RAN WG1#83 **R1-157203**
Anaheim, USA, 15th - 22nd November 2015

Source: **Ericsson**
Title: **Remaining Details of Codebook Subset Restriction**
Agenda Item: **6.2.4.1**
Document for: **Discussion and Decision**

---

1 Introduction

In RAN1#82bis, it was agreed that codebook subset restriction (CSR) is supported for FD-MIMO with Class A CSI reporting where [1]

- A 2D-beam corresponds to (l_1, l_2) in $\boldsymbol{X}_1 \otimes \boldsymbol{X}_2$
- CSR is configured via RRC signaling
- A subset of 2D-beams (l_1, l_2) are forbidden, i.e. not allowed to be reported according to the CSR configuration
  - A forbidden 2D-beam is not allowed in reporting with any rank
- Rank restriction is also supported
- Codebook Subset Restriction can be also applied to $\boldsymbol{W}_2$
- Number of PMI bits does not vary according to restricted subset
  - Note: Codebook subset restriction targets e.g. performance/capacity, as in Rel-8 to Rel-12

In [2], it was further agreed that

- For $\boldsymbol{W}_1$ CSR, a bitmap of $(N_1 O_1 N_2 O_2)$ bits indicates 2D-beams subset restriction (referred to as *Beam-Subset-Restriction* in the rest of the contribution),
- 8 additional bits bitmap indicates rank restriction
- An RRC parameter for CSR on Class A i_2 (i.e. $\boldsymbol{W}_2$) will be introduced.
  - Bitmap of all possible codewords per rank

In this contribution, we provide further details on the specification impact of supporting CSR for FD-MIMO. As the final details of the Class A codebook have only been agreed for rank 1, we make an assumption of the codebook for higher ranks, for the sake of this discussion, based on the contribution [4]. This codebook is also given in the appendix in Section 5.

2 Specification Impact for CSR

A 2D beam is identified by the parameters l_1 and l_2 and corresponds to two vectors for the first and second dimension respectively.

$$\mathbf{v}(l_1) = \begin{bmatrix} 1 & e^{j\frac{2\pi l_1}{O_1 N_1}} & \dots & e^{j\frac{2\pi l_1 (N_1-1)}{O_1 N_1}} \end{bmatrix}^T, \mathbf{u}(l_2) = \begin{bmatrix} 1 & e^{j\frac{2\pi l_2}{O_2 N_2}} & \dots & e^{j\frac{2\pi l_2 (N_2-1)}{O_2 N_2}} \end{bmatrix}^T$$

Since $l_1 = 0, \dots, N_1 O_1 - 1$, $l_2 = 0, \dots, N_2 O_2 - 1$, there are a total $N_1 O_1 N_2 O_2$ such 2D beams

2.1 Mapping between *Beam-Subset-Restriction* bits and 2D Beams

Let the bitmap for the *Beam-Subset-Restriction* RRC parameter be formed by the bit sequence $a_{S-1}, a_{S-2}, \dots, a_3, a_2, a_1, a_0$ where a_0 is the least significant bit (LSB), a_{S-1} is the most significant bit (MSB), and $S = N_1 O_1 N_2 O_2$. The index n of a bit a_n in the *Beam-Subset-Restriction* bitmap can be mapped to a 2D beam using the 'first dimension first' mapping scheme shown in Figure 1.

Now let (l'_1, l'_2) identify a forbidden 2D-beam (i.e., a 2D beam that is not allowed to be reported in any rank) corresponding to a DFT vector with index l'_1 in the first dimension and a DFT vector with index l'_2 in the second dimension. The indices l'_1 and l'_2 can be referred to as forbidden beam indices. If a bit in the *Beam-Subset-Restriction* bitmap indicates a forbidden 2D beam, then this bit corresponds to only one combination of a forbidden beam index l'_1 in the first dimension and a forbidden beam index l'_2 in the second dimension out of the $O_1 N_1 O_2 N_2$ possible combinations of the first beam index l_1 and the second beam index l_2.

If we assume a 'first dimension first' mapping scheme, then the bit a_n forbids a 2D beam with indices

$$l'_1 = n - N_1 O_1 \left\lfloor \frac{n}{N_1 O_1} \right\rfloor$$

$$l'_2 = \left\lfloor \frac{n}{N_1 O_1} \right\rfloor.$$

Equivalently, n can be calculated from l'_1 and l'_2 with $n = l'_1 + N_1 O_1 l'_2$. An example of the first dimension first mapping scheme with $(N_1, N_2) = (2,2)$ and $(O_1, O_2) = (4,4)$ is illustrated in Figure 2.

Proposal 1: The n^{th} bit a_n of the *Beam-Subset-Restriction* bitmap is used to forbid a 2D beam with indices (l'_1, l'_2), where $l'_1 = n - N_1 O_1 \left\lfloor \frac{n}{N_1 O_1} \right\rfloor$ and $l'_2 = \left\lfloor \frac{n}{N_1 O_1} \right\rfloor$.

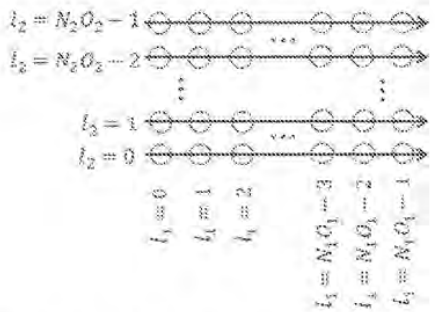

Figure 1. A 'first dimension first' mapping between *Beam-Subset-Restriction* bits and 2D beams.

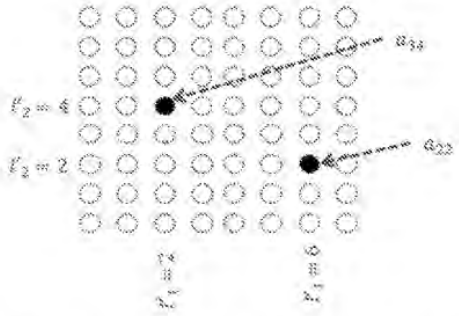

Figure 2. Example of 'first dimension first' mapping.

2.2 Beam Restriction across Ranks

Considering the rank 1 Class A codebook agreed in [1], a given rank-1 codeword $W^{(1)}_{m_1,m_2,n}$ as defined in **Error! Reference source not found.** of the Appendix is forbidden (i.e., not allowed to be reported), if $m_1 = l'_1$ and $m_2 = l'_2$ simultaneously, where the range of (m_1, m_2) are determined by the value of *Config* (see [1] for details) and (l'_1, l'_2) represents the forbidden beam indices of any 2D beam that is not allowed to be reported (as signaled by the *Beam-Subset-Restriction* bitmap).

For the Class A codebooks of ranks 2, 3, and 4 described in Sections 5.2, 5.3, and 5.4, respectively, a given codeword (which, depending on the rank, can be defined by **Error! Reference source not found.**), **Error! Reference source not found.**), **Error! Reference source not found.**, or **Error! Reference source not found.** in the Appendix) is forbidden (i.e., not allowed to be reported) if **either or both** of the following two conditions are met

Condition 1: $m_1 = l'_1$ and $m_2 = l'_2$
Condition 2: $m'_1 = l'_1$ and $m'_2 = l'_2$

where possible values of (m_1, m_2) and (m'_1, m'_2) are determined by the value of *Config* (see [3]-[4] for details). Furthermore, (l'_1, l'_2) represents any 2D beam that is not allowed to be reported (as signaled by the *Beam-Subset-Restriction* bitmap).

For the rank 5-8 Class A codebooks of Section 5.5, the rules for applying beam restriction has to be formulated slightly differently since codewords for ranks 5-8 are indexed with $i_{1,1}$ and $i_{1,2}$ as opposed to the parameters m_1, m_2, m'_1, m'_2. For the rank 5-8 Class A codebooks, a given rank 5-8 codeword is forbidden (i.e. not allowed to be reported) if the codeword contains at least one forbidden 2D beam (as defined jointly by l'_1 and l'_2). This happens if at least one of the conditions given in Table 1 is met. In Table 1, the $\delta_{l,j}$ values are those from the rank 5-8 codebooks which are determined by the parameters N_1, N_2, and the configuration associated with the codebook (see [4] for details).

The $i_{1,1}$ and $i_{1,2}$ indices are the PMI indices corresponding to the first and second dimensions. The conditions in each column of the table are checked a column at a time according to the rank (denoted by r). Conditions 1-3 apply to codewords with ranks 5, 6, 7, or 8, while Condition 4 only applies to codewords with ranks 7 or 8. For at least one applicable column (i.e., condition), if forbidden beam index l'_1 is equal to the table entry on the first row of the column, and if forbidden beam index l'_2 is simultaneously equal to the table entry on the second row of the column, then codeword $W^{(r)}_{i_{1,1},i_{1,2}}$ is forbidden (i.e., not allowed to be reported).

Table 1: Rank 5-8 Codeword Restriction

	Condition 1	Condition 2	Condition 3	Condition 4
Rank	5,6,7,8	5,6,7,8	5,6,7,8	7,8
l'_1	$s_1 i_{1,1}$	$s_1 i_{1,1} + \delta_{1,1}$	$s_1 i_{1,1} + \delta_{1,2}$	$s_1 i_{1,1} + \delta_{1,3}$
l'_2	$s_2 i_{1,2}$	$s_2 i_{1,2} + \delta_{2,1}$	$s_2 i_{1,2} + \delta_{2,2}$	$s_2 i_{1,2} + \delta_{2,3}$

Proposal 2: Specify the following rules for applying beam restriction of a forbidden 2D beam (l'_1, l'_2) across ranks:

- **For rank 1-4:** A codeword indicated by the parameters m_1, m_2 or parameters m_1, m_2, m'_1, m'_2 shall not be reported if either or both of these conditions are met:
  - Condition 1: $m_1 = l'_1$ and $m_2 = l'_2$ simultaneously
  - Condition 2: $m'_1 = l'_1$ and $m'_2 = l'_2$ simultaneously
- **For rank 5-8:** A codeword shall not be reported if at least one of the conditions given in Table 1 are met by both rows corresponding to l'_1 and l'_2 simultaneously.

2.3 CSR Configuration Conflict Cases

When a UE signaled with more than one of the CSR restrictions (i.e. *Beam-Subset-Restriction, CLASS A i2 restriction and* Rank Restriction) , different codewords may be forbidden by the different bitmaps. Some rules are needed in terms of which restriction bitmap has the higher priority in case of conflicts, e.g. a codeword is allowed in one restriction bitmap but not allowed in another restriction bitmap(s). The more straightforward rule is to not allow a codeword belonging to a particular rank to be reported if the codeword is forbidden by any one of the multiple restriction bitmaps.

Proposal 3: A codeword belonging to a particular rank is not allowed to be reported if the codeword is forbidden by any one of the multiple CSR restriction bitmaps.

3 Conclusion

In this contribution, we provide further details on the specification impact of supporting CSR for FD-MIMO based on the CSR parameters agreed in RAN1#82bis. We make the following proposals:

Proposal 1: The n^{th} bit a_n of the *Beam-Subset-Restriction* bitmap is used to forbid a 2D beam with indices (l'_1, l'_2), where $l'_1 = n - N_1 O_1 \left\lfloor \frac{n}{N_1 O_1} \right\rfloor$ and $l'_2 = \left\lfloor \frac{n}{N_1 O_1} \right\rfloor$.

Proposal 2: Specify the following rules for applying beam restriction of a forbidden 2D beam (l'_1, l'_2) across ranks:

- **For rank 1-4:** A codeword indicated by the parameters m_1, m_2 or parameters m_1, m_2, m'_1, m'_2 not be reported if either or both of these conditions are met:
  - Condition 1: $m_1 = l'_1$ and $m_2 = l'_2$ simultaneously
  - Condition 2: $m'_1 = l'_1$ and $m'_2 = l'_2$ simultaneously
- **For rank 5-8:** A codeword shall not be reported if at least one of the conditions given in Table 1 are met by both rows corresponding to l'_1 and l'_2 simultaneously

Table 1: Rank 5-8 Codeword Restriction

	Condition 1	Condition 2	Condition 3	Condition 4
Rank	5,6,7,8	5,6,7,8	5,6,7,8	7,8
$l'_1 =$	$s_1 i_{1,1}$	$s_1 i_{1,1} + \delta_{1,1}$	$s_1 i_{1,1} + \delta_{1,2}$	$s_1 i_{1,1} + \delta_{1,3}$
$l'_2 =$	$s_2 i_{1,2}$	$s_2 i_{1,2} + \delta_{2,1}$	$s_2 i_{1,2} + \delta_{2,2}$	$s_2 i_{1,2} + \delta_{2,3}$

Proposal 3: A codeword belonging to a particular rank is not allowed to be reported if the codeword is forbidden by any one of the multiple CSR restriction bitmaps.

4 References

[1] R1-156217, "WF on class A and class B CSI reporting for Rel.13 EB/FD-MIMO", AT&T, Beijing Xinwei Telecom Tech., CATR, CATT, CHTTL, CMCC, Deutsche Telekom, Ericsson, ETRI, Huawei, HiSilicon, ITRI, Kathrein-Werke KG, KDDI, KT Corporation, Nokia Networks, NTT DOCOMO, Samsung, Sony Corporation, 3GPP TSG-RAN WG1#82bis, Malmö, Sweden, October 5-9, 2015.

[2] RAN1 Chairman's Notes, 3GPP TSG-RAN WG1#82bis, Malmö, Sweden, October 5-9, 2015.

[3] R1-156335, "Joint Proposal on Rank 2 Codebook for Class A CSI Reporting", Samsung, Ericsson, 3GPP TSG-RAN WG1#82bis, Malmö, Sweden, October 5-9, 2015.

[4] R1-156390, "Joint proposal on rank 3-8 codebook," Samsung, Ericsson, NTT DOCOMO, CATT, 3GPP TSG-RAN WG1 #83, Anaheim, USA, November 16-20, 2015.

5 Appendix: Class A Codebook Agreements and Proposals

5.1 Rank-1 Class A Codebook

In [1], a class A codebook for rank-1 was agreed. As per the agreement, a selected rank-1 codeword $W^{(1)}_{m_1,m_2,n}$ can be represented as

$$W^{(1)}_{m_1,m_2,n} = \frac{1}{\sqrt{Q}}\begin{bmatrix} v_{m_1} \otimes u_{m_2} \\ \varphi_n v_{m_1} \otimes u_{m_2} \end{bmatrix}, \tag{1}$$

wherein $\varphi_n = e^{j\pi n/2}$ and $Q \in \{8,12,16\}$. In **Error! Reference source not found.**), the single layer of data is transmitted on the 2-dimensional beam involving the m_1^{th} beam in the first dimension and the m_2^{th} beam in the second dimension where

$$v_{m_1} = \begin{bmatrix} 1 & e^{j\frac{2\pi m_1}{O_1 N_1}} & \cdots & e^{j\frac{2\pi m_1 (N_1-1)}{O_1 N_1}} \end{bmatrix}^T, \tag{2}$$

$$u_{m_2} = \begin{bmatrix} 1 & e^{j\frac{2\pi m_2}{O_2 N_2}} & \cdots & e^{j\frac{2\pi m_2 (N_2-1)}{O_2 N_2}} \end{bmatrix}^T. \tag{3}$$

Further details of the agreed class A codebook rank-1 codebook can be found in [1].

5.2 Rank-2 Class A Codebook

A class A codebook for rank-2 is proposed in [3]. In [3], a selected rank-2 codeword $W^{(2)}_{m_1,m_2,m_1',m_2',n}$ can be represented as

$$W^{(2)}_{m_1,m_2,m_1',m_2',n} = \frac{1}{\sqrt{2Q}}\begin{bmatrix} v_{m_1} \otimes u_{m_2} & v_{m_1'} \otimes u_{m_2'} \\ \varphi_n v_{m_1} \otimes u_{m_2} & -\varphi_n v_{m_1'} \otimes u_{m_2'} \end{bmatrix}. \tag{4}$$

In **Error! Reference source not found.**, the first layer of data is transmitted on the 2-dimensional beam involving the m_1^{th} beam in the first dimension and the m_2^{th} beam in the second dimension; the second layer of data is transmitted on the 2-dimensional beam involving the $(m_1')^{th}$ beam in the first dimension and the $(m_2')^{th}$ beam in the second dimension. Further details of the proposed class A codebook for rank-2 can be found in [3].

5.3 Rank-3 Class A Codebook

A joint proposal for rank-3 class A codebook is presented in [4]. A selected rank-3 codeword can either be represented by $W^{(3)}_{m_1,m_1',m_2,m_2'}$ or $\tilde{W}^{(3)}_{m_1,m_1',m_2,m_2'}$, where

$$W^{(3)}_{m_1,m_1',m_2,m_2'} = \frac{1}{\sqrt{3Q}}\begin{bmatrix} v_{m_2} \otimes u_{m_2} & v_{m_1} \otimes u_{m_2} & v_{m_1'} \otimes u_{m_2'} \\ v_{m_1'} \otimes u_{m_2} & -v_{m_1} \otimes u_{m_2} & -v_{m_1'} \otimes u_{m_2'} \end{bmatrix}. \tag{5}$$

$$\tilde{W}^{(3)}_{m_1,m_1',m_2,m_2'} = \frac{1}{\sqrt{3Q}}\begin{bmatrix} v_{m_1}\otimes u_{m_2} & v_{m_1}\otimes u_{m_2'} & v_{m_1}\otimes u_{m_2'} \\ v_{m_1'}\otimes u_{m_2} & v_{m_1'}\otimes u_{m_2'} & -v_{m_1'}\otimes u_{m_2'} \end{bmatrix}. \quad (6)$$

Further details of the proposed class A codebook for rank-3 can be found in [4].

5.4 Rank-4 Class A Codebook

A class A codebook for rank-4 is proposed in [4]. In [4], a selected rank-4 codeword $W^{(4)}_{m_1,m_1',m_2,m_2',n}$ can be represented as

$$W^{(4)}_{m_1,m_1',m_2,m_2',n} = \frac{1}{\sqrt{4Q}}\begin{bmatrix} v_{m_1}\otimes u_{m_2} & v_{m_1}\otimes u_{m_2'} & v_{m_1}\otimes u_{m_2} & v_{m_1}\otimes u_{m_2'} \\ \varphi_n v_{m_1'}\otimes u_{m_2} & \varphi_n v_{m_1'}\otimes u_{m_2'} & -\varphi_n v_{m_1'}\otimes u_{m_2} & -\varphi_n v_{m_1'}\otimes u_{m_2'} \end{bmatrix}. \quad (7)$$

Further details of the proposed class A codebook for rank-4 can be found in [4].

5.5 Class A Codebooks for Ranks 5-8

Class A codebooks for ranks 5-8 are proposed in [4]. A precoding matrix codeword for rank r ($r = 5,6,7,8$) is denoted as $W^{(r)}_{i_{1,1},i_{1,2}}$. The precoding matrix codewords $W^{(r)}_{i_{1,1},i_{1,2}}$, $r = 5,6,7,8$ are then defined as

$$W^{(5)}_{i_{1,1},i_{1,2}} = \frac{1}{\sqrt{5Q}}\begin{bmatrix} v_{s_{i_{1,1}}}\otimes u_{s_{2i_{1,2}}} & v_{s_{i_{1,1}}}\otimes u_{s_{2i_{1,2}}+\delta_{2,2}} & v_{s_{i_{1,1}}+\delta_{1,1}}\otimes u_{s_{2i_{1,2}}+\delta_{2,1}} & v_{s_{i_{1,1}}+\delta_{1,1}}\otimes u_{s_{2i_{1,2}}+\delta_{2,2}} & v_{s_{i_{1,1}}+\delta_{1,2}}\otimes u_{s_{2i_{1,2}}+\delta_{2,2}} \\ v_{s_{i_{1,1}}}\otimes u_{s_{2i_{1,2}}} & -v_{s_{i_{1,1}}}\otimes u_{s_{2i_{1,2}}+\delta_{2,2}} & v_{s_{i_{1,1}}+\delta_{1,1}}\otimes u_{s_{2i_{1,2}}+\delta_{2,1}} & -v_{s_{i_{1,1}}+\delta_{1,1}}\otimes u_{s_{2i_{1,2}}+\delta_{2,2}} & v_{s_{i_{1,1}}+\delta_{1,2}}\otimes u_{s_{2i_{1,2}}+\delta_{2,2}} \end{bmatrix} \quad (8)$$

$$W^{(6)}_{i_{1,1},i_{1,2}} = \frac{1}{\sqrt{6Q}}\begin{bmatrix} v_{s_{i_{1,1}}}\otimes u_{s_{2i_{1,2}}} & v_{s_{i_{1,1}}}\otimes u_{s_{2i_{1,2}}} & v_{s_{i_{1,1}}+\delta_{1,1}}\otimes u_{s_{2i_{1,2}}+\delta_{2,1}} & v_{s_{i_{1,1}}+\delta_{1,1}}\otimes u_{s_{2i_{1,2}}+\delta_{2,2}} & v_{s_{i_{1,1}}+\delta_{1,2}}\otimes u_{s_{2i_{1,2}}+\delta_{2,1}} & v_{s_{i_{1,1}}+\delta_{1,2}}\otimes u_{s_{2i_{1,2}}+\delta_{2,2}} \\ v_{s_{i_{1,1}}}\otimes u_{s_{2i_{1,2}}} & -v_{s_{i_{1,1}}}\otimes u_{s_{2i_{1,2}}} & v_{s_{i_{1,1}}+\delta_{1,1}}\otimes u_{s_{2i_{1,2}}+\delta_{2,1}} & -v_{s_{i_{1,1}}+\delta_{1,1}}\otimes u_{s_{2i_{1,2}}+\delta_{2,2}} & v_{s_{i_{1,1}}+\delta_{1,2}}\otimes u_{s_{2i_{1,2}}+\delta_{2,1}} & -v_{s_{i_{1,1}}+\delta_{1,2}}\otimes u_{s_{2i_{1,2}}+\delta_{2,2}} \end{bmatrix} \quad (9)$$

$$W^{(7)}_{i_{1,1},i_{1,2}} = \frac{1}{\sqrt{7Q}}\begin{bmatrix} v_{s_{i_{1,1}}}\otimes u_{s_{2i_{1,2}}} & v_{s_{i_{1,1}}}\otimes u_{s_{2i_{1,2}}} & v_{s_{i_{1,1}}+\delta_{1,1}}\otimes u_{s_{2i_{1,2}}+\delta_{2,1}} & v_{s_{i_{1,1}}+\delta_{1,1}}\otimes u_{s_{2i_{1,2}}+\delta_{2,2}} & v_{s_{i_{1,1}}+\delta_{1,2}}\otimes u_{s_{2i_{1,2}}+\delta_{2,1}} & v_{s_{i_{1,1}}+\delta_{1,2}}\otimes u_{s_{2i_{1,2}}+\delta_{2,2}} & v_{s_{i_{1,1}}+\delta_{1,3}}\otimes u_{s_{2i_{1,2}}+\delta_{2,3}} \\ v_{s_{i_{1,1}}}\otimes u_{s_{2i_{1,2}}} & -v_{s_{i_{1,1}}}\otimes u_{s_{2i_{1,2}}} & v_{s_{i_{1,1}}+\delta_{1,1}}\otimes u_{s_{2i_{1,2}}+\delta_{2,1}} & -v_{s_{i_{1,1}}+\delta_{1,1}}\otimes u_{s_{2i_{1,2}}+\delta_{2,2}} & v_{s_{i_{1,1}}+\delta_{1,2}}\otimes u_{s_{2i_{1,2}}+\delta_{2,1}} & -v_{s_{i_{1,1}}+\delta_{1,2}}\otimes u_{s_{2i_{1,2}}+\delta_{2,2}} & v_{s_{i_{1,1}}+\delta_{1,3}}\otimes u_{s_{2i_{1,2}}+\delta_{2,3}} \end{bmatrix} \quad (10)$$

$$W^{(8)}_{i_{1,1},i_{1,2}} = \frac{1}{\sqrt{8Q}}\begin{bmatrix} v_{s_{i_{1,1}}}\otimes u_{s_{2i_{1,2}}} & v_{s_{i_{1,1}}}\otimes u_{s_{2i_{1,2}}} & v_{s_{i_{1,1}}+\delta_{1,1}}\otimes u_{s_{2i_{1,2}}+\delta_{2,1}} & v_{s_{i_{1,1}}+\delta_{1,1}}\otimes u_{s_{2i_{1,2}}+\delta_{2,2}} & v_{s_{i_{1,1}}+\delta_{1,2}}\otimes u_{s_{2i_{1,2}}+\delta_{2,1}} & v_{s_{i_{1,1}}+\delta_{1,2}}\otimes u_{s_{2i_{1,2}}+\delta_{2,2}} & v_{s_{i_{1,1}}+\delta_{1,3}}\otimes u_{s_{2i_{1,2}}+\delta_{2,3}} & v_{s_{i_{1,1}}+\delta_{1,3}}\otimes u_{s_{2i_{1,2}}+\delta_{2,3}} \\ v_{s_{i_{1,1}}}\otimes u_{s_{2i_{1,2}}} & -v_{s_{i_{1,1}}}\otimes u_{s_{2i_{1,2}}} & v_{s_{i_{1,1}}+\delta_{1,1}}\otimes u_{s_{2i_{1,2}}+\delta_{2,1}} & -v_{s_{i_{1,1}}+\delta_{1,1}}\otimes u_{s_{2i_{1,2}}+\delta_{2,2}} & v_{s_{i_{1,1}}+\delta_{1,2}}\otimes u_{s_{2i_{1,2}}+\delta_{2,1}} & -v_{s_{i_{1,1}}+\delta_{1,2}}\otimes u_{s_{2i_{1,2}}+\delta_{2,2}} & v_{s_{i_{1,1}}+\delta_{1,3}}\otimes u_{s_{2i_{1,2}}+\delta_{2,3}} & -v_{s_{i_{1,1}}+\delta_{1,3}}\otimes u_{s_{2i_{1,2}}+\delta_{2,3}} \end{bmatrix} \quad (11)$$

In **Error! Reference source not found.-Error! Reference source not found.**, the values of $\delta_{1,1}, \delta_{1,2}, \delta_{1,3}, \delta_{2,1}, \delta_{2,2}, \delta_{2,3}$ are determined by the parameters N_1, N_2, and the configuration associated with the codebook. Further details of these values can be found in [4].

Electronic Patent Application Fee Transmittal	
Application Number:	
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Title of Invention:	Codebook Subset Restriction Signaling
First Named Inventor/Applicant Name:	Sebastian Faxér
Filer:	Justin J. Leonard/Katya Fox
Attorney Docket Number:	4015-9595 / P45698-US2
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Claims in excess of 20	1615	12	80	960
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First Named Inventor/Applicant Name:	Sebastian Faxér
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First Named Inventor/Applicant Name:	Sebastian Faxér
Customer Number:	24112
Filer:	Justin J. Leonard/Kristi Dunshee
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Attorney Docket Number (if applicable)	4015-9080 / P45698-US1

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CODEBOOK SUBSET RESTRICTION SIGNALING

BACKGROUND

[0001] The use of multiple antennas at the transmitter and/or the receiver of a wireless communication system can significantly boost the capacity and coverage of a wireless communication system. Such MIMO systems can exploit the spatial dimension of the communication channel. For example, several information-carrying signals can be sent in parallel using the transmit antennas and still be separated by signal processing at the receiver. By adapting the transmission to the current channel conditions, significant additional gains can be achieved. One form of adaptation is to dynamically, from one TTI to another, adjust the number of simultaneously transmitted information streams carrying signals to what the channel can support. This is commonly referred to as (transmission) rank adaptation. Precoding is another form of adaptation where the phases and amplitudes of the aforementioned signals are adjusted to better fit the current channel properties. The signals form a vector-valued signal and the adjustment can be thought of as multiplication by a precoder matrix. A common approach is to select the precoder matrix from a finite and indexed set, a so-called codebook. Such codebook-based precoding is an integral part of the LTE standard, as well as in many other wireless communication standards.

[0002] Codebook based precoding can be regarded as a form of channel quantization. A typical approach (c.f. LTE and MIMO HSDPA) is to let the receiver recommend a suitable precoder matrix to the transmitter by signaling the precoder matrix indicator (PMI) over a feedback link. To limit signaling overhead, it is generally important to keep the codebook size as small as possible if the feedback link has a limited capacity. This however needs to be balanced against the performance impact since with a larger codebook it is possible to better match the current channel conditions.

[0003] For example, in the LTE downlink, the UE reports the PMI to the eNodeB either periodically on PUCCH or aperiodic on the PUSCH. The former is a rather narrow bit pipe where CSI feedback is reported in a semi-statically configured and periodic fashion. On the other hand, reporting on PUSCH is dynamically triggered as part of the uplink grant. Thus, the eNodeB can schedule CSI transmissions in a dynamic fashion. In contrast to the PUCCH where the number of physical bits is currently limited to 20, the reports on PUSCH can be considerably larger. Thus, for feedback on PUCCH a small codebook size is desirable to keep the signaling overhead down. However, for feedback on PUSCH a larger codebook size is desirable to increase performance, since the capacity on the feedback channel is not as limited in this case.

[0004] The desired size of the codebook may also depend on the transmission scheme used. For example, a codebook used in MU-MIMO operation could benefit more from having a larger number of elements than a codebook used in SU-MIMO operation. In the former case, a large spatial resolution is important to allow for sufficient UE separation.

[0005] A convenient way to support different codebook sizes is to use a large codebook with many elements by default and apply *codebook subset restriction* in the scenarios where a smaller codebook is beneficial. With codebook subset restriction, a subset of the precoders in the codebook is restricted so that the UE has a smaller set of possible precoders to choose from. This effectively reduces the size of the codebook implying that the search for the best PMI can be done on the smaller unrestricted set of precoders, thereby also reducing the UE computational requirements for this particular search. Typically, the eNodeB would signal the codebook subset restriction to the UE by means of a bitmap in an a dedicated message part of the AntennaInfo information element (see the RRC specification, TS 36.331), one bit for each precoder in the codebook, where a 1 would indicate that the precoder is restricted (meaning that the UE is not allowed to choose and report said precoder). Thus, for a codebook with N elements, a bitmap of length N would be used to signal the codebook subset restriction. This allows for full flexibility for the eNodeB to restrict every possible subset of the codebook. There

are thus 2^N possible codebook subset restriction configurations.For large antenna arrays with many antenna elements, the effective beams become narrow and a codebook containing many precoders is required for the intended coverage area. Furthermore, for two-dimensional antenna arrays, the codebook size increases quadratically since the precoders in the codebook need to span two dimensions, typically the horizontal and vertical domain. Thus, the codebook size (i.e. the total number of possible precoding matrices W) can be very large. Signaling a codebook subset restriction in the conventional way by means of a bitmap with one bit for every precoder can thus impose a large overhead, especially if the codebook subset restriction (CSR) is frequently updated or if there are many users served by the cell which each has to receive the CSR.

SUMMARY

[0006] One or more embodiments herein advantageously lower the signaling overhead imposed by transmitting a codebook subset restriction, while still allowing for flexibility in configuring different codebook subset restrictions.

[0007] Embodiments herein therefore generally include methods to reduce the number of bits required for signaling a codebook subset restriction configuration to a UE. The methods in one or more of these embodiments do so by:

- Utilizing an explicit or implicit assumption about which sets of precoders are more likely to be restricted, and/or
- Associating a group of precoders with a single codebook subset restriction bit.

DETAILED DESCRIPTION

[0008] According to the flowchart of Figure 1, a network node in a wireless communication network (e.g., an eNB in the network) signals a codebook subset restriction (CSR) configuration to a wireless communication device (e.g., a UE). The device then sends a channel state information (CSI) report back to the network. This CSI report suggests which of different

possible precoders in a codebook the network should use for transmitting to the deivce, but the CSI report is restricted in the sense that there is a subset of precoders that cannot be reported by the device; that is, all precoders in the codebook cannot be selected and reported by the device. This restriction is defined by the signaled CSR configuration.

[0009] In more detail, for a precoder codebook X, consisting of N precoders, there are 2^N possible codebook subset restriction configurations since each precoder can individually either be allowed or restricted (a restricted configuration is not allowed to be used). Each configuration can be represented by a bitmap of N bits, where each bit corresponds to a certain precoder and the value of the bit then indicates whether the precoder is restricted or not. If each of the 2^N configurations is equiprobable and independent, this is the optimal representation of a codebook subset restriction configuration with respect to the expected length (in bits) of the representation and it provides full flexibility.

[0010] However, embodiments herein recognize that, if certain configurations are more likely to be used than others, and/or if the restriction of one precoder is highly correlated to the restriction of another precoder, then this signaling leads to unnecessarily high signaling overhead. One or more embodiments herein include methods to reduce this signaling overhead; that is, reduce the number of bits required for signaling a codebook subset restriction configuration to a wireless communication device from the network. In some embodiments, for example, the methods utilize an implicit assumption about which sets of precoders are more likely to be restricted or which sets of precoders are likely to be jointly restricted.

Method in A Network Node

[0011] According to one embodiment shown in Figure 2, for example, a method is implemented by a network node (e.g., a base station) for signaling to a wireless communication device which precoders in a codebook are restricted from being used. For each of one or more groups of precoders in the codebook, the method includes identifying one or more reference

configurations for the group (Block 110). Each reference configuration is one of different possible configurations that restrict different subgroups of precoders in the group from being used. One of the reference configurations for a group may be for instance whichever one of the different possible configurations has the maximum probability of being signaled, e.g., as predicted or estimated based on empirical observations or implicit assumptions. Regardless, the method further includes identifying, from the different possible configurations for the group, the actual configuration to be signaled for the group (Block 120).

[0012] The method also includes generating signaling to indicate the actual configuration for the group (Block 130). This entails generating the signaling as a bit pattern whose length depends on (i) whether the actual configuration matches one of the one or more reference configurations; and/or (ii) which reference configuration the actual configuration matches. In some embodiments, for example, when the actual configuration matches any reference configuration, the bit pattern's length is shorter than when the actual configuration does not match any reference configuration. In other embodiments, when the actual configuration matches a particular one of multiple reference configurations, the bit pattern's length is shorter than when the actual configuration matches a different one of the reference configurations. Regardless, this process (Blocks 110-130) is repeated for each of one or more groups of precoders in the codebook (Blocks 100, 140, and 150). Finally, the method includes sending the generated signaling to the wireless communication device (Block 160).

[0013] This approach may in some sense be viewed as a sort of compression algorithm for CSR signaling. Indeed, the approach advantageously reduces the signaling overhead when, over the course of a given time period, the overhead savings realized by signaling bit patterns with relatively shorter lengths outweighs the overhead costs imposed by signaling bit patterns with relatively longer lengths. Depending on the relative lengths of the bit patterns, then, the approach may for instance reduce signaling overhead when the one or more reference

configurations (or particular ones of the one or more reference configurations) are signaled more often than not.

[0014] In at least some embodiments, therefore, a reference configuration has a higher likelihood or probability of being signaled than any other possible configurations that are not reference configurations. For example, the one or more reference configurations for a group may include whichever one(s) of the different possible configurations for the group have the highest probability of being signaled. Different reference configurations that have different probabilities of being signaled may be represented with bit patterns of different lengths, where reference configurations with higher probabilities are represented with bit patterns of shorter lengths. That is, certain configurations that are deemed more probable may be represented with a fewer number of bits, while other configurations, that are deemed less probable to be used, may be represented with a larger number of bits.

[0015] In some embodiments, the one or more reference configurations may be predefined to be particular one(s) of the possible configurations, e.g., based on an (implicit) assumption that the particular configuration(s) have the highest probability of being signaled. For example, an implicit assumption is made on how the network is likely to be configured. Hence, here certain configurations are considered more likely than others but there are no actual probability values estimated for the different configurations.

[0016] In other embodiments, though, the network node determines signaling probabilities of different configurations, e.g., based on empirical observations and compares those probabilities to identify the configuration(s) with the highest probability. In one embodiment for example signaling probabilities are estimated through logging of network data. Hence, here it may be possible to estimate actual probabilities for the different configurations. In general, therefore, the knowledge on "how likely" a certain configuration is may be obtained in many ways.

[0017] In some embodiments, only a single reference configuration is defined for a group. In this case, the signaling is generated as a short bit pattern when the actual configuration matches the reference configuration and as a long bit pattern when the actual configuration does not match the reference configuration. Different long bit patterns in this regard are respectively defined for signaling different configurations (other than the reference configuration, for which the short bit pattern is defined for signaling). A long bit pattern of course has more bits than a short bit pattern (e.g., N bits vs. 1 bit).

[0018] In other embodiments, multiple reference configurations are defined for a group. In this case, the signaling may be generated as bit patterns that have different lengths when the actual configuration matches different reference configurations. These lengths may correspond to how likely it is that the reference configurations will be signaled. The bit pattern's length may be shortest when the actual configuration matches a particular one of the reference configurations (e.g., the one with the maximum probability of being signaled), may be next shortest when the actual configuration matches a different reference configuration (e.g., the one with the next highest signaling probability), and may be longest when the actual configuration does not match any of the reference configurations.

[0019] In some embodiments, bit patterns signaling non-reference configurations are encoded as a combination of a so-called "non-reference bit pattern" and a "bitmap." The non-reference bit pattern is defined for signaling that the actual configuration for the group does not match any reference configuration for the group. The non-reference bit pattern may for instance be the complement of a bit pattern defined for signaling a reference configuration. For example, when only a single reference configuration is defined for a group, the bit pattern signaling that reference configuration may simply be a single bit with a value of "1", whereas the non-reference bit pattern may be a single bit with a value of "0". Regardless, the bitmap portion of the bit pattern comprises different bits respectively dedicated to indicating whether different precoders in the group are restricted from being used.