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KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD,
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RW, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ,
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ML, MR, NE, SN, TD, TG).

Declarations under Rule 4.17:

- as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))
- as to the applicant's entitlement to claim the priority of the earlier application (Rule 4.17(iii))

[Continued on next page]

(54) Title: METHODS AND APPARATUS TO IMPROVE CHANNEL ESTIMATION IN COMMUNICATION SYSTEMS

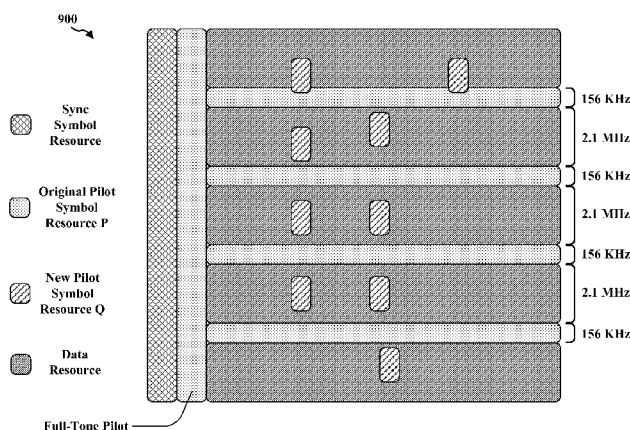


FIG. 9

(57) **Abstract:** A method, an apparatus, and a computer program product for wireless communication are provided. The apparatus generates a codeword, determines at least one puncture to the codeword based on allowing a legacy receiver to decode the codeword without knowledge of the at least one puncture, replaces each of the at least one puncture with a pilot, and transmits the codeword. The apparatus may also generate an IEEE 802.11 codeword having pilots in a first set of subcarriers, and puncture the codeword with additional pilots unknown to a legacy receiver in a second set of subcarriers. Accordingly, when an original set of pilot symbols is insufficient or inappropriately placed in a resource structure, a codeword may be transmitted with a new pilot structure capable of being decoded by legacy receivers not aware of the new pilot structure.



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- *with international search report (Art. 21(3))*
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INTERNATIONAL SEARCH REPORT

International application No

PCT/US2013/036818

A. CLASSIFICATION OF SUBJECT MATTER
 INV. H04L5/00
 ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
 H04L

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

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

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

| Category* | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|-----------|---|----------------------------|
| X | US 2011/244877 A1 (FARAJIDANA AMIR [US] ET AL) 6 October 2011 (2011-10-06) paragraph [0006] - paragraph [0007] paragraph [0049] - paragraph [0051] ----- | 1-7, 18-24, 35-41,52 |
| X | US 2011/286423 A1 (BERGGREN FREDRIK [SE] ET AL) 24 November 2011 (2011-11-24) paragraph [0023] - paragraph [0031] ----- | 1-7, 18-24, 35-41,52 |
| X | US 2011/199986 A1 (FONG MO-HAN [CA] ET AL) 18 August 2011 (2011-08-18) paragraph [0058] - paragraph [0063] ----- -/- | 1-7, 18-24, 35-41,52 |



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

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Name and mailing address of the ISA/

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C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

| Category* | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|-----------|---|-----------------------------|
| A | Erik Dahlman ET AL: "4G LTE/LTE-Advanced for Mobile Broadband - Chapter 10" In: "4G LTE/LTE-Advanced for Mobile Broadband - Chapter 10", 29 March 2011 (2011-03-29), XP055046016, pages 145-202, page 159 - page 161 ----- | 1-7, 18-24, 35-41,52 |
| X | US 2011/252139 A1 (BHATTAD KAPIL [US] ET AL) 13 October 2011 (2011-10-13) figure 4 paragraph [0034] paragraph [0042] paragraph [0049] paragraph [0051] paragraph [0055] - paragraph [0059] ----- | 8-17, 25-34, 42-51,53 |
| A | US 2005/195734 A1 (SANDELL MAGNUS [GB] ET AL) 8 September 2005 (2005-09-08) figure 3 ----- | 1-52 |

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2013/036818

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:
2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:
3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

see additional sheet

1. ☒ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. ☐ As all searchable claims could be searched without effort justifying an additional fees, this Authority did not invite payment of additional fees.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:
4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.
- ☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.
- ☒ No protest accompanied the payment of additional search fees.

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

This International Searching Authority found multiple (groups of) inventions in this international application, as follows:

1. claims: 1-7, 18-24, 35-41, 52

Puncturing and decodability

2. claims: 8-17, 25-34, 42-51, 53

Pilot distribution across subcarriers

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/US2013/036818

| Patent document cited in search report | Publication date | Patent family member(s) | Publication date |
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