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APPLICATION NO.	ISSUE DATE	PATENT NO.	ATTORNEY DOCKET NO.	CONFIRMATION NO.
12/026,480	03/26/2013	8406753	AND01 080	3162

79172 7590 03/06/2013

Duane Morris LLP
505 9th Street, N.W.
Suite 1000
Washington, DC 20004

ISSUE NOTIFICATION

The projected patent number and issue date are specified above.

Determination of Patent Term Adjustment under 35 U.S.C. 154 (b)
(application filed on or after May 29, 2000)

The Patent Term Adjustment is 1135 day(s). Any patent to issue from the above-identified application will include an indication of the adjustment on the front page.

If a Continued Prosecution Application (CPA) was filed in the above-identified application, the filing date that determines Patent Term Adjustment is the filing date of the most recent CPA.

Applicant will be able to obtain more detailed information by accessing the Patent Application Information Retrieval (PAIR) WEB site (http://pair.uspto.gov).

Any questions regarding the Patent Term Extension or Adjustment determination should be directed to the Office of Patent Legal Administration at (571)-272-7702. Questions relating to issue and publication fee payments should be directed to the Application Assistance Unit (AAU) of the Office of Data Management (ODM) at (571)-272-4200.

APPLICANT(s) (Please see PAIR WEB site http://pair.uspto.gov for additional applicants):

Martin Alles, Vienna, VA;
John Carlson, Dulles, VA;
George Maher, Herndon, VA;
Selcuk Mazlum, Leesburg, VA;

The United States represents the largest, most dynamic marketplace in the world and is an unparalleled location for business investment, innovation, and commercialization of new technologies. The USA offers tremendous resources and advantages for those who invest and manufacture goods here. Through SelectUSA, our nation works to encourage and facilitate business investment. To learn more about why the USA is the best country in the world to develop technology, manufacture products, and grow your business, visit SelectUSA.gov.

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

PTO/SB/08a (01-10)
Approved for use through 07/31/2012. OMB 0651-0031
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE

Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it contains a valid OMB control number.

INFORMATION DISCLOSURE STATEMENT BY APPLICANT
(Not for submission under 37 CFR 1.99)

Application Number	12026480
Filing Date	2008-02-05
First Named Inventor	Martin Alles et al.
Art Unit	2617
Examiner Name	Unassigned
Attorney Docket Number	AND01 080

U.S.PATENTS

Examiner Initial*	Cite No	Patent Number	Kind Code[1]	Issue Date	Name of Patentee or Applicant of cited Document	Pages,Columns,Lines where Relevant Passages or Relevant Figures Appear
/E.S./	1	5960341	A	1999-09-28	LeBlanc	

If you wish to add additional U.S. Patent citation information please click the Add button.

U.S.PATENT APPLICATION PUBLICATIONS

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
/E.S./	1	20050040968	A1	2005-02-24	Damarla et al.	
/E.S./	2	20050266855	A1	2005-12-01	Zeng	

If you wish to add additional U.S. Published Application citation information please click the Add button.

FOREIGN PATENT DOCUMENTS

Examiner Initial*	Cite No	Foreign Document Number[3]	Country Code[2] i	Kind Code[4]	Publication Date	Name of Patentee or Applicant of cited Document	Pages,Columns,Lines where Relevant Passages or Relevant Figures Appear	T[5]
/E.S./	1	1471688	EP	A2	2004-10-27	AT&T		☐
/E.S./	2	02082832	WO	A	2002-10-17 ~~2004-10-27~~	MacDonald		☐

Changes applied to document,
/N.W.S./
2/19/2019

PART B - FEE(S) TRANSMITTAL

Complete and send this form, together with applicable fee(s), to: Mail **Mail Stop ISSUE FEE**
Commissioner for Patents
P.O. Box 1450
Alexandria, Virginia 22313-1450
or Fax (571)-273-2885

INSTRUCTIONS: This form should be used for transmitting the ISSUE FEE and PUBLICATION FEE (if required). Blocks 1 through 5 should be completed where appropriate. All further correspondence including the Patent, advance orders and notification of maintenance fees will be mailed to the current correspondence address as indicated unless corrected below or directed otherwise in Block 1, by (a) specifying a new correspondence address; and/or (b) indicating a separate "FEE ADDRESS" for maintenance fee notifications.

CURRENT CORRESPONDENCE ADDRESS (Note: Use Block 1 for any change of address)

79172 7590 01/29/2013
Duane Morris LLP
505 9th Street, N.W.
Suite 1000
Washington, DC 20004

Note: A certificate of mailing can only be used for domestic mailings of the Fee(s) Transmittal. This certificate cannot be used for any other accompanying papers. Each additional paper, such as an assignment or formal drawing, must have its own certificate of mailing or transmission.

Certificate of Mailing or Transmission

I hereby certify that this Fee(s) Transmittal is being deposited with the United States Postal Service with sufficient postage for first class mail in an envelope addressed to the Mail Stop ISSUE FEE address above, or being facsimile transmitted to the USPTO (571) 273-2885, on the date indicated below.

(Depositor's name)
(Signature)
(Date)

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
12/026,480	02/05/2008	Martin Alles	AND01 080	3162

TITLE OF INVENTION: SYSTEM AND METHOD FOR GENERATING A LOCATION ESTIMATE USING UNIFORM AND NON-UNIFORM GRID POINTS

APPLN. TYPE	SMALL ENTITY	ISSUE FEE DUE	PUBLICATION FEE DUE	PREV. PAID ISSUE FEE	TOTAL FEE(S) DUE	DATE DUE
nonprovisional	NO	$1770	$300	$0	$2070	04/29/2013

EXAMINER	ART UNIT	CLASS-SUBCLASS
STEPHEN, EMEM O	2641	455-422100

1. Change of correspondence address or indication of "Fee Address" (37 CFR 1.363).

☐ Change of correspondence address (or Change of Correspondence Address form PTO/SB/122) attached.

☐ "Fee Address" indication (or "Fee Address" Indication form PTO/SB/47; Rev 03-02 or more recent) attached. **Use of a Customer Number is required.**

2. For printing on the patent front page, list

(1) the names of up to 3 registered patent attorneys or agents OR, alternatively,

(2) the name of a single firm (having as a member a registered attorney or agent) and the names of up to 2 registered patent attorneys or agents. If no name is listed, no name will be printed.

1 Duane Morris LLP
2
3

3. ASSIGNEE NAME AND RESIDENCE DATA TO BE PRINTED ON THE PATENT (print or type)

PLEASE NOTE: Unless an assignee is identified below, no assignee data will appear on the patent. If an assignee is identified below, the document has been filed for recordation as set forth in 37 CFR 3.11. Completion of this form is NOT a substitute for filing an assignment.

(A) NAME OF ASSIGNEE: Andrew LLC

(B) RESIDENCE: (CITY and STATE OR COUNTRY): Hickory, North Carolina

Please check the appropriate assignee category or categories (will not be printed on the patent) : ☐ Individual ☒ Corporation or other private group entity ☐ Government

4a. The following fee(s) are submitted:

☒ Issue Fee

☒ Publication Fee (No small entity discount permitted)

☐ Advance Order - # of Copies _____

4b. Payment of Fee(s): **(Please first reapply any previously paid issue fee shown above)**

☐ A check is enclosed.

☐ Payment by credit card. Form PTO-2038 is attached.

☒ The Director is hereby authorized to charge the required fee(s), any deficiency, or credit any overpayment, to Deposit Account Number 04-1679 (enclose an extra copy of this form).

5. **Change in Entity Status** (from status indicated above)

☐ a. Applicant claims SMALL ENTITY status. See 37 CFR 1.27.

☐ b. Applicant is no longer claiming SMALL ENTITY status. See 37 CFR 1.27(g)(2).

NOTE: The Issue Fee and Publication Fee (if required) will not be accepted from anyone other than the applicant; a registered attorney or agent; or the assignee or other party in interest as shown by the records of the United States Patent and Trademark Office.

Authorized Signature /Mark C. Comtois/ Date 14 February 2013

Typed or printed name Mark C. Comtois Registration No. 46,285

This collection of information is required by 37 CFR 1.311. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 12 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, Virginia 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, Virginia 22313-1450.

Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number.

Electronic Patent Application Fee Transmittal

Application Number:	12026480
Filing Date:	05-Feb-2008
Title of Invention:	SYSTEM AND METHOD FOR GENERATING A LOCATION ESTIMATE USING UNIFORM AND NON-UNIFORM GRID POINTS
First Named Inventor/Applicant Name:	Martin Alles
Filer:	Mark Charles Comtois/laureen ponder
Attorney Docket Number:	AND01 080

Filed as Large Entity

Utility under 35 USC 111(a) Filing Fees

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Basic Filing:				
Pages:				
Claims:				
Miscellaneous-Filing:				
Petition:				
Patent-Appeals-and-Interference:				
Post-Allowance-and-Post-Issuance:				
Utility Appl issue fee	1501	1	1770	1770
Publ. Fee- early, voluntary, or normal	1504	1	300	300

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Extension-of-Time:				
Miscellaneous:				
		Total in USD ($)		**2070**

Electronic Acknowledgement Receipt	
EFS ID:	14958710
Application Number:	12026480
International Application Number:	
Confirmation Number:	3162
Title of Invention:	SYSTEM AND METHOD FOR GENERATING A LOCATION ESTIMATE USING UNIFORM AND NON-UNIFORM GRID POINTS
First Named Inventor/Applicant Name:	Martin Alles
Customer Number:	79172
Filer:	Mark Charles Comtois/laureen ponder
Filer Authorized By:	Mark Charles Comtois
Attorney Docket Number:	AND01 080
Receipt Date:	14-FEB-2013
Filing Date:	05-FEB-2008
Time Stamp:	12:43:54
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	yes
Payment Type	Deposit Account
Payment was successfully received in RAM	$2070
RAM confirmation Number	12498
Deposit Account	041679
Authorized User	
The Director of the USPTO is hereby authorized to charge indicated fees and credit any overpayment as follows: Charge any Additional Fees required under 37 C.F.R. Section 1.21 (Miscellaneous fees and charges)	

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Issue Fee Payment (PTO-85B)	12026480IF.pdf	96652 d7c39e34204e0c05dc22268e2fdfb2d055f62970	no	1
Warnings:					
Information:					
2	Fee Worksheet (SB06)	fee-info.pdf	31836 14e7f8af3029fc4a4219b0e9c6399c0cdeddaa2d	no	2
Warnings:					
Information:					
		Total Files Size (in bytes):	128488		

This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503.

<u>New Applications Under 35 U.S.C. 111</u>
If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.

<u>National Stage of an International Application under 35 U.S.C. 371</u>
If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.

<u>New International Application Filed with the USPTO as a Receiving Office</u>
If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

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NOTICE OF ALLOWANCE AND FEE(S) DUE

79172 7590 01/29/2013

Duane Morris LLP
505 9th Street, N.W.
Suite 1000
Washington, DC 20004

EXAMINER
STEPHEN, EMEM O

ART UNIT	PAPER NUMBER
2641	

DATE MAILED: 01/29/2013

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
12/026,480	02/05/2008	Martin Alles	AND01 080	3162

TITLE OF INVENTION: SYSTEM AND METHOD FOR GENERATING A LOCATION ESTIMATE USING UNIFORM AND NON-UNIFORM GRID POINTS

APPLN. TYPE	SMALL ENTITY	ISSUE FEE DUE	PUBLICATION FEE DUE	PREV. PAID ISSUE FEE	TOTAL FEE(S) DUE	DATE DUE
nonprovisional	NO	$1770	$300	$0	$2070	04/29/2013

THE APPLICATION IDENTIFIED ABOVE HAS BEEN EXAMINED AND IS ALLOWED FOR ISSUANCE AS A PATENT. PROSECUTION ON THE MERITS IS CLOSED. THIS NOTICE OF ALLOWANCE IS NOT A GRANT OF PATENT RIGHTS. THIS APPLICATION IS SUBJECT TO WITHDRAWAL FROM ISSUE AT THE INITIATIVE OF THE OFFICE OR UPON PETITION BY THE APPLICANT. SEE 37 CFR 1.313 AND MPEP 1308.

THE ISSUE FEE AND PUBLICATION FEE (IF REQUIRED) MUST BE PAID WITHIN THREE MONTHS FROM THE MAILING DATE OF THIS NOTICE OR THIS APPLICATION SHALL BE REGARDED AS ABANDONED. THIS STATUTORY PERIOD CANNOT BE EXTENDED. SEE 35 U.S.C. 151. THE ISSUE FEE DUE INDICATED ABOVE DOES NOT REFLECT A CREDIT FOR ANY PREVIOUSLY PAID ISSUE FEE IN THIS APPLICATION. IF AN ISSUE FEE HAS PREVIOUSLY BEEN PAID IN THIS APPLICATION (AS SHOWN ABOVE), THE RETURN OF PART B OF THIS FORM WILL BE CONSIDERED A REQUEST TO REAPPLY THE PREVIOUSLY PAID ISSUE FEE TOWARD THE ISSUE FEE NOW DUE.

HOW TO REPLY TO THIS NOTICE:

I. Review the SMALL ENTITY status shown above.

If the SMALL ENTITY is shown as YES, verify your current SMALL ENTITY status:

A. If the status is the same, pay the TOTAL FEE(S) DUE shown above.

B. If the status above is to be removed, check box 5b on Part B - Fee(s) Transmittal and pay the PUBLICATION FEE (if required) and twice the amount of the ISSUE FEE shown above, or

If the SMALL ENTITY is shown as NO:

A. Pay TOTAL FEE(S) DUE shown above, or

B. If applicant claimed SMALL ENTITY status before, or is now claiming SMALL ENTITY status, check box 5a on Part B - Fee(s) Transmittal and pay the PUBLICATION FEE (if required) and 1/2 the ISSUE FEE shown above.

II. PART B - FEE(S) TRANSMITTAL, or its equivalent, must be completed and returned to the United States Patent and Trademark Office (USPTO) with your ISSUE FEE and PUBLICATION FEE (if required). If you are charging the fee(s) to your deposit account, section "4b" of Part B - Fee(s) Transmittal should be completed and an extra copy of the form should be submitted. If an equivalent of Part B is filed, a request to reapply a previously paid issue fee must be clearly made, and delays in processing may occur due to the difficulty in recognizing the paper as an equivalent of Part B.

III. All communications regarding this application must give the application number. Please direct all communications prior to issuance to Mail Stop ISSUE FEE unless advised to the contrary.

IMPORTANT REMINDER: Utility patents issuing on applications filed on or after Dec. 12, 1980 may require payment of maintenance fees. It is patentee's responsibility to ensure timely payment of maintenance fees when due.

PART B - FEE(S) TRANSMITTAL

Complete and send this form, together with applicable fee(s), to: Mail **Mail Stop ISSUE FEE**
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Alexandria, Virginia 22313-1450
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INSTRUCTIONS: This form should be used for transmitting the ISSUE FEE and PUBLICATION FEE (if required). Blocks 1 through 5 should be completed where appropriate. All further correspondence including the Patent, advance orders and notification of maintenance fees will be mailed to the current correspondence address as indicated unless corrected below or directed otherwise in Block 1, by (a) specifying a new correspondence address; and/or (b) indicating a separate "FEE ADDRESS" for maintenance fee notifications.

CURRENT CORRESPONDENCE ADDRESS (Note: Use Block 1 for any change of address)

79172 7590 01/29/2013
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505 9th Street, N.W.
Suite 1000
Washington, DC 20004

Note: A certificate of mailing can only be used for domestic mailings of the Fee(s) Transmittal. This certificate cannot be used for any other accompanying papers. Each additional paper, such as an assignment or formal drawing, must have its own certificate of mailing or transmission.

Certificate of Mailing or Transmission

I hereby certify that this Fee(s) Transmittal is being deposited with the United States Postal Service with sufficient postage for first class mail in an envelope addressed to the Mail Stop ISSUE FEE address above, or being facsimile transmitted to the USPTO (571) 273-2885, on the date indicated below.

(Depositor's name)
(Signature)
(Date)

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
12/026,480	02/05/2008	Martin Alles	AND01 080	3162

TITLE OF INVENTION: SYSTEM AND METHOD FOR GENERATING A LOCATION ESTIMATE USING UNIFORM AND NON-UNIFORM GRID POINTS

APPLN. TYPE	SMALL ENTITY	ISSUE FEE DUE	PUBLICATION FEE DUE	PREV. PAID ISSUE FEE	TOTAL FEE(S) DUE	DATE DUE
nonprovisional	NO	$1770	$300	$0	$2070	04/29/2013

EXAMINER	ART UNIT	CLASS-SUBCLASS
STEPHEN, EMEM O	2641	455-422100

1. Change of correspondence address or indication of "Fee Address" (37 CFR 1.363).

❑ Change of correspondence address (or Change of Correspondence Address form PTO/SB/122) attached.

❑ "Fee Address" indication (or "Fee Address" Indication form PTO/SB/47; Rev 03-02 or more recent) attached. **Use of a Customer Number is required.**

2. For printing on the patent front page, list

(1) the names of up to 3 registered patent attorneys or agents OR, alternatively,

(2) the name of a single firm (having as a member a registered attorney or agent) and the names of up to 2 registered patent attorneys or agents. If no name is listed, no name will be printed.

1 _____

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3 _____

3. ASSIGNEE NAME AND RESIDENCE DATA TO BE PRINTED ON THE PATENT (print or type)

PLEASE NOTE: Unless an assignee is identified below, no assignee data will appear on the patent. If an assignee is identified below, the document has been filed for recordation as set forth in 37 CFR 3.11. Completion of this form is NOT a substitute for filing an assignment.

(A) NAME OF ASSIGNEE (B) RESIDENCE: (CITY and STATE OR COUNTRY)

Please check the appropriate assignee category or categories (will not be printed on the patent) : ❑ Individual ❑ Corporation or other private group entity ❑ Government

4a. The following fee(s) are submitted:

❑ Issue Fee

❑ Publication Fee (No small entity discount permitted)

❑ Advance Order - # of Copies _____

4b. Payment of Fee(s): **(Please first reapply any previously paid issue fee shown above)**

❑ A check is enclosed.

❑ Payment by credit card. Form PTO-2038 is attached.

❑ The Director is hereby authorized to charge the required fee(s), any deficiency, or credit any overpayment, to Deposit Account Number _____ (enclose an extra copy of this form).

5. **Change in Entity Status** (from status indicated above)

❑ a. Applicant claims SMALL ENTITY status. See 37 CFR 1.27.

❑ b. Applicant is no longer claiming SMALL ENTITY status. See 37 CFR 1.27(g)(2).

NOTE: The Issue Fee and Publication Fee (if required) will not be accepted from anyone other than the applicant; a registered attorney or agent; or the assignee or other party in interest as shown by the records of the United States Patent and Trademark Office.

Authorized Signature _____ Date _____

Typed or printed name _____ Registration No. _____

This collection of information is required by 37 CFR 1.311. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 12 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, Virginia 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, Virginia 22313-1450.

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APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
12/026,480	02/05/2008	Martin Alles	AND01 080	3162

79172 7590 01/29/2013

Duane Morris LLP
505 9th Street, N.W.
Suite 1000
Washington, DC 20004

EXAMINER
STEPHEN, EMEM O

ART UNIT	PAPER NUMBER
2641	

DATE MAILED: 01/29/2013

Determination of Patent Term Adjustment under 35 U.S.C. 154 (b)
(application filed on or after May 29, 2000)

The Patent Term Adjustment to date is 866 day(s). If the issue fee is paid on the date that is three months after the mailing date of this notice and the patent issues on the Tuesday before the date that is 28 weeks (six and a half months) after the mailing date of this notice, the Patent Term Adjustment will be 866 day(s).

If a Continued Prosecution Application (CPA) was filed in the above-identified application, the filing date that determines Patent Term Adjustment is the filing date of the most recent CPA.

Applicant will be able to obtain more detailed information by accessing the Patent Application Information Retrieval (PAIR) WEB site (http://pair.uspto.gov).

Any questions regarding the Patent Term Extension or Adjustment determination should be directed to the Office of Patent Legal Administration at (571)-272-7702. Questions relating to issue and publication fee payments should be directed to the Customer Service Center of the Office of Patent Publication at 1-(888)-786-0101 or (571)-272-4200.

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.

Notice of Allowability	Application No.	Applicant(s)	
	12/026,480	ALLES ET AL.	
	Examiner	Art Unit	
	EMEM STEPHEN	2641	

-- The MAILING DATE of this communication appears on the cover sheet with the correspondence address--

All claims being allowable, PROSECUTION ON THE MERITS IS (OR REMAINS) CLOSED in this application. If not included herewith (or previously mailed), a Notice of Allowance (PTOL-85) or other appropriate communication will be mailed in due course. **THIS NOTICE OF ALLOWABILITY IS NOT A GRANT OF PATENT RIGHTS.** This application is subject to withdrawal from issue at the initiative of the Office or upon petition by the applicant. See 37 CFR 1.313 and MPEP 1308.

1. ☒ This communication is responsive to *the communication of 12/20/2011*.

2. ☐ An election was made by the applicant in response to a restriction requirement set forth during the interview on _____; the restriction requirement and election have been incorporated into this action.

3. ☒ The allowed claim(s) is/are *1-57*. As a result of the allowed claim(s), you may be eligible to benefit from the **Patent Prosecution Highway** program at a participating intellectual property office for the corresponding application. For more information, please see http://www.uspto.gov/patents/init_events/pph/index.jsp or send an inquiry to PPHfeedback@uspto.gov .

4. ☐ Acknowledgment is made of a claim for foreign priority under 35 U.S.C. § 119(a)-(d) or (f).
   a) ☐ All b) ☐ Some* c) ☐ None of the:
      1. ☐ Certified copies of the priority documents have been received.
      2. ☐ Certified copies of the priority documents have been received in Application No. _____ .
      3. ☐ Copies of the certified copies of the priority documents have been received in this national stage application from the International Bureau (PCT Rule 17.2(a)).

   * Certified copies not received: _____.

Applicant has THREE MONTHS FROM THE "MAILING DATE" of this communication to file a reply complying with the requirements noted below. Failure to timely comply will result in ABANDONMENT of this application.
THIS THREE-MONTH PERIOD IS NOT EXTENDABLE.

5. ☐ CORRECTED DRAWINGS (as "replacement sheets") must be submitted.
   ☐ including changes required by the attached Examiner's Amendment / Comment or in the Office action of Paper No./Mail Date _____.

Identifying indicia such as the application number (see 37 CFR 1.84(c)) should be written on the drawings in the front (not the back) of each sheet. Replacement sheet(s) should be labeled as such in the header according to 37 CFR 1.121(d).

6. ☐ DEPOSIT OF and/or INFORMATION about the deposit of BIOLOGICAL MATERIAL must be submitted. Note the attached Examiner's comment regarding REQUIREMENT FOR THE DEPOSIT OF BIOLOGICAL MATERIAL.

Attachment(s)

1. ☐ Notice of References Cited (PTO-892)
2. ☒ Information Disclosure Statements (PTO/SB/08), Paper No./Mail Date _____
3. ☐ Examiner's Comment Regarding Requirement for Deposit of Biological Material
4. ☐ Interview Summary (PTO-413), Paper No./Mail Date _____ .
5. ☐ Examiner's Amendment/Comment
6. ☒ Examiner's Statement of Reasons for Allowance
7. ☐ Other _____.

/MELODY MEHRPOUR/
Primary Examiner, Art Unit 2641

DETAILED ACTION

Allowable Subject Matter

1. Claims 1-57 are allowed.

2. The following is an examiner's statement of reasons for allowance:

Claims 1-57 are allowed in view of the Applicants argument of 12/20/2011.

Therefore, this limitation, in conjunction with the other limitations recited in claims are novel and unobvious in view of the prior art of record.

Any comments considered necessary by Applicant must be submitted no later than the payment of the issue fee and, to avoid processing delays, should preferably accompany the issue fee. Such submissions should be clearly labeled "Comments on Statement of Reasons for Allowance".

Conclusion

Any inquiry concerning this communication or earlier communications from the examiner should be directed to EMEM STEPHEN whose telephone number is (571)272-8129. The examiner can normally be reached on 8-5 Mon-Fri..

If attempts to reach the examiner by telephone are unsuccessful, the examiner's supervisor, Charles Appiah can be reached on 571 272 7904. The fax phone number for the organization where this application or proceeding is assigned is 571-273-8300.

Information regarding the status of an application may be obtained from the Patent Application Information Retrieval (PAIR) system. Status information for published applications may be obtained from either Private PAIR or Public PAIR. Status information for unpublished applications is available through Private PAIR only. For more information about the PAIR system, see http://pair-direct.uspto.gov. Should you have questions on access to the Private PAIR system, contact the Electronic Business Center (EBC) at 866-217-9197 (toll-free). If you would like assistance from a USPTO Customer Service Representative or access to the automated information system, call 800-786-9199 (IN USA OR CANADA) or 571-272-1000.

/EMEM STEPHEN/
Examiner, Art Unit 2641

EAST Search History

EAST Search History (Interference)

Ref #	Hits	Search Query	DBs	Default Operator	Plurals	Time Stamp
S21	3	((calibrat$3 adj3 (parameter point)) and grid and ((estimat$3 measure$4 evaluat$3) adj3 (report result)) and set and function).clm.	USPAT; UPAD	OR	ON	2013/01/17 14:58

1/ 24/ 2013 3:18:04 PM
C:\ Users\ eekong\ Documents\ EAST\ Workspaces\ 12026480(3).wsp

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)		
	Application Number	12026480
	Filing Date	2008-02-05
	First Named Inventor	ALLES et al.
	Art Unit	2617
	Examiner Name	Emem O. Stephen
	Attorney Docket Number	AND01 080

U.S.PATENTS						
Examiner Initial*	Cite No	Patent Number	Kind Code[1]	Issue Date	Name of Patentee or Applicant of cited Document	Pages,Columns,Lines where Relevant Passages or Relevant Figures Appear
/E.S./	1	8155394	B2	2012-04-10	Allegra et al.	
/E.S./	2	8106818	B2	2012-01-31	Bhattacharya et al.	
/E.S./	3	8106817	B2	2012-01-31	Bhattacharya et al.	
/E.S./	4	8068855	B2	2011-11-29	Dressler et al.	
/E.S./	5	8068802	B2	2011-11-29	Bhattacharya et al.	
/E.S./	6	8013785	B2	2011-09-06	Bhattacharya et al.	
/E.S./	7	7899467	B2	2011-03-01	Feuerstein et al.	
/E.S./	8	7848762	B2	2010-12-07	Gordon et al.	

INFORMATION DISCLOSURE STATEMENT BY APPLICANT
(Not for submission under 37 CFR 1.99)

Application Number	12026480
Filing Date	2008-02-05
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Art Unit	2617
Examiner Name	Emem O. Stephen
Attorney Docket Number	AND01 080

/E.S./	9	7796966	B2	2010-09-14	Bhattacharya et al.	
/E.S./	10	7753278	B2	2010-07-13	Spain Jr. et al.	
/E.S./	11	7734298	B2	2010-06-08	Bhattacharya et al.	
/E.S./	12	7725111	B2	2010-05-25	Dressler et al.	
/E.S./	13	7460505	B2	2008-12-02	Spain	
/E.S./	14	7433695	B2	2008-10-07	Gordon et al.	
/E.S./	15	7433652	B2	2008-10-07	Durgin	
/E.S./	16	7383051	B2	2008-06-03	Spain Jr. et al.	
/E.S./	17	7257414	B2	2007-08-14	Spain Jr. et al.	
/E.S./	18	7233799	B2	2007-06-19	Spain Jr.	
/E.S./	19	7167714	B2	2007-01-23	Dressler et al.	

INFORMATION DISCLOSURE STATEMENT BY APPLICANT
(Not for submission under 37 CFR 1.99)

Application Number	12026480
Filing Date	2008-02-05
First Named Inventor	ALLES et al.
Art Unit	2617
Examiner Name	Emem O. Stephen
Attorney Docket Number	AND01 080

/E.S./	20	7116987	B2	2006-10-03	Spain Jr. et al.	
/E.S./	21	6944465	B2	2005-09-13	Spain et al.	
/E.S./	22	6782265	B2	2004-08-24	Perez-Breva et al.	
/E.S./	23	6591112	B1	2003-07-08	Siccardo et al.	
/E.S./	24	6449486	B1	2002-09-10	Rao	
/E.S./	25	6393294	B1	2002-05-21	Perez-Breva et al.	
/E.S./	26	6281834	B1	2001-08-28	Stilp	
/E.S./	27	6269246	B1	2001-07-31	Rao et al.	
/E.S./	28	6115605		2000-09-05	Siccardo et al.	
/E.S./	29	6108558		2000-08-22	Vanderspool II	
/E.S./	30	6097709		2000-08-01	Kuwabara	

INFORMATION DISCLOSURE STATEMENT BY APPLICANT
(Not for submission under 37 CFR 1.99)

Application Number	12026480
Filing Date	2008-02-05
First Named Inventor	ALLES et al.
Art Unit	2617
Examiner Name	Emem O. Stephen
Attorney Docket Number	AND01 080

/E.S./	31	7250907	B2	2007-07-31	Krumm et al.	

If you wish to add additional U.S. Patent citation information please click the Add button.

U.S.PATENT APPLICATION PUBLICATIONS

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
/E.S./	1	20040203539	A1	2004-10-14	Benes et al.	

If you wish to add additional U.S. Published Application citation information please click the Add button.

FOREIGN PATENT DOCUMENTS

Examiner Initial*	Cite No	Foreign Document Number[3]	Country Code[2] i	Kind Code[4]	Publication Date	Name of Patentee or Applicant of cited Document	Pages,Columns,Lines where Relevant Passages or Relevant Figures Appear	T[5]
	1							☐

If you wish to add additional Foreign Patent Document citation information please click the Add button

NON-PATENT LITERATURE DOCUMENTS

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]
/E.S./	1	RICK ROBERTS, "Project: IEEE P802.15 Working Group for Wireless Personal Area Networks (WPANS)," Harris Corporation, Melbourne Florida, October 4, 2004, pages1-11.	☐
/E.S./	2	STEPHANIE BELL, "A Beginners Guide to Uncertainty of Measurement, The National Physics Laboratory of the United Kingdom of Great Britain and Northern Ireland, Teddington, Middlesex, UK, 2001, pages1-41.	☐

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

Receipt date: 10/31/2012		
INFORMATION DISCLOSURE STATEMENT BY APPLICANT (**Not for submission under 37 CFR 1.99)**	Application Number	12026480 12026480 - GAU: 2641
	Filing Date	2008-02-05
	First Named Inventor	ALLES et al.
	Art Unit	2617
	Examiner Name	Emem O. Stephen
	Attorney Docket Number	AND01 080

EXAMINER SIGNATURE			
Examiner Signature	/Emem Stephen/ (01/24/2013)	Date Considered	01/24/2013

*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.

CONSIDERED: /E.S./ (01/24/2013)

INFORMATION DISCLOSURE STATEMENT BY APPLICANT

(Not for submission under 37 CFR 1.99)

Application Number	12026480
Filing Date	2008-02-05
First Named Inventor	ALLES et al.
Art Unit	2617
Examiner Name	Emem O. Stephen
Attorney Docket Number	AND01 080

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

☒ That no item of information contained in the information disclosure statement was cited in a communication from a foreign patent office in a counterpart foreign application, and, to the knowledge of the person signing the certification after making reasonable inquiry, no item of information contained in the information disclosure statement was known to any individual designated in 37 CFR 1.56(c) more than three months prior to the filing of the information disclosure statement. See 37 CFR 1.97(e)(2).

☐ 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	/Mark C. Comtois/	Date (YYYY-MM-DD)	2012-10-31
Name/Print	Mark C. Comtois	Registration Number	46285

This collection of information is required by 37 CFR 1.97 and 1.98. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 1 hour to complete, including gathering, preparing and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

Issue Classification

Application/Control No.	Applicant(s)/Patent Under Reexamination
12026480	ALLES ET AL.
Examiner	**Art Unit**
EMEM STEPHEN	2641

CPC

Symbol				Type	Version
H04W	84	/	00		
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CPC Combination Sets

Symbol				Type	Set	Ranking	Version
		/					
		/					

US ORIGINAL CLASSIFICATION

CLASS	SUBCLASS
455	422.1

CROSS REFERENCE(S)

CLASS	SUBCLASS (ONE SUBCLASS PER BLOCK)				
455	425				

INTERNATIONAL CLASSIFICATION

CLAIMED					NON-CLAIMED				
H	0	4	W	4 / 00 (2009.01.01)	H	0	4	W	24 / 00 (2009.01.01)

/EMEM STEPHEN/ Examiner.Art Unit 2641 (Assistant Examiner)	1/24/2013 (Date)	**Total Claims Allowed:** 57	
/MELODY MEHRPOUR/ Primary Examiner.Art Unit 2641 (Primary Examiner)	01/28/2013 (Date)	O.G. Print Claim(s) 1	O.G. Print Figure 1

U.S. Patent and Trademark Office

Part of Paper No. 20130124

Issue Classification	Application/Control No.	Applicant(s)/Patent Under Reexamination
	12026480	ALLES ET AL.
	Examiner	**Art Unit**
	EMEM STEPHEN	2641

/EMEM STEPHEN/ Examiner.Art Unit 2641	1/24/2013	**Total Claims Allowed:**	
(Assistant Examiner)	(Date)	57	
/MELODY MEHRPOUR/ Primary Examiner.Art Unit 2641	01/28/2013	O.G. Print Claim(s)	O.G. Print Figure
(Primary Examiner)	(Date)	1	1

U.S. Patent and Trademark Office

Part of Paper No. 20130124

Issue Classification	Application/Control No.	Applicant(s)/Patent Under Reexamination
	12026480	ALLES ET AL.
	Examiner	**Art Unit**
	EMEM STEPHEN	2641

☐ Claims renumbered in the same order as presented by applicant ☐ CPA ☐ T.D. ☐ R.1.47

Final	Original	Final	Original	Final	Original	Final	Original	Final	Original	Final	Original	Final	Original	Final	Original
1	1	17	17	33	33	49	49								
2	2	18	18	34	34	50	50								
3	3	19	19	35	35	51	51								
4	4	20	20	36	36	52	52								
5	5	21	21	37	37	53	53								
6	6	22	22	38	38	54	54								
7	7	23	23	39	39	55	55								
8	8	24	24	40	40	56	56								
9	9	25	25	41	41	57	57								
10	10	26	26	42	42										
11	11	27	27	43	43										
12	12	28	28	44	44										
13	13	29	29	45	45										
14	14	30	30	46	46										
15	15	31	31	47	47										
16	16	32	32	48	48										

/EMEM STEPHEN/ Examiner.Art Unit 2641 (Assistant Examiner)	1/24/2013 (Date)	**Total Claims Allowed:** 57	
/MELODY MEHRPOUR/ Primary Examiner.Art Unit 2641 (Primary Examiner)	01/28/2013 (Date)	O.G. Print Claim(s) 1	O.G. Print Figure 1

Search Notes	Application/Control No.	Applicant(s)/Patent Under Reexamination
	12026480	ALLES ET AL.
	Examiner	Art Unit
	EMEM STEPHEN	2617

CPC- SEARCHED		
Symbol	Date	Examiner

CPC COMBINATION SETS - SEARCHED		
Symbol	Date	Examiner

US CLASSIFICATION SEARCHED			
Class	Subclass	Date	Examiner
455	422.1,423,425,433,404.2,456.1-456.3, 435.1-435.5		
340	870.04-870.05,988-989, 991,995.18,995.25,423.19		
342	357.2-357.25,357.62		
702	85,94-95,150		

SEARCH NOTES		
Search Notes	Date	Examiner
east search	8/12/2011	es
east update	1/24/2013	es

INTERFERENCE SEARCH			
US Class/ CPC Symbol	US Subclass / CPC Group	Date	Examiner
455	422.1	1/17/2013	es

EAST Search History

EAST Search History (Prior Art)

Ref #	Hits	Search Query	DBs	Default Operator	Plurals	Time Stamp
S1	5	(calibrat$3 adj3 (parameter point)) same grid same ((estimat$3 measure$4 evaluat$3) adj3 (report result)) same (select$3 elect$3 designat$3 choos$3) near8 point same set same function	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2013/01/17 13:29
S2	5	(calibrat$3 adj3 (parameter point)) same grid same ((estimat$3 measure$4 evaluat$3) adj3 (report result)) same (select$3 elect$3 designat$3 choos$3) same point same set same function	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2013/01/17 13:50
S3	5	(calibrat$3 adj3 (parameter point)) same grid same ((estimat$3 measure$4 evaluat$3) adj3 (report result)) same set same function	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2013/01/17 13:50
S4	16	(calibrat$3 adj3 (parameter point)) same grid same ((estimat$3 measure$4 evaluat$3) adj3 (report result))	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2013/01/17 13:50
S5	76	("20060240843" | "6871077" | "20050136945a1" | "20050164712a1" | "20060141998a1" | "20050040968" | "20060030333" | "20080261611" | "6871077" | "20050243936" | "20060030333" | "20050243936" | "20070155401" | "20080158059" | "20080248811" | "20080261614" | "20060116130a1" | "6920329" | "20050266855" | "20080161015" | "20030139188" | "20040252752a1" | "20070087689a1" | "6987979" | "6104344" | "20070155489" | "20080261612" | "20040043775a1" | "20050058182a1" | "20050192026a1" | "20060003695a1" | "20060240836a1" | "5372144" | "5423067" | "6097959" | "20050078033" | "20080132247" | "20080261613" | "20090005061" | "20030203738" | "20040203921" | "20060154607a1" | "6859172" | "20060030333" | "20070225912" | "20020172223" | "20060003775" | "20060240843" | "20070111746" |	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2013/01/17 14:03

		"20080132244" | "20030190919a1" | "20040218664a1" | "20060125695a1" | "20070202885a1" | "6201803" | "20050243936" | "20030064734" | "20080137524" | "20040132466a1" | "5952969" | "5987329").PN.				
S6	16117	S4 adn S5	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2013/01/17 14:20
S7	0	(calibrat$3 adj3 (parameter data point)) same grid same ((estimat$3 measure$4 evaluat$3) adj3 (report result)) and S5	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2013/01/17 14:21
S8	20	(calibrat$3 adj3 (parameter data point)) same grid same ((estimat$3 measure$4 evaluat$3) adj3 (report result))	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2013/01/17 14:24
S9	22230	(455/422.1,423,425,433,404.2,456.1-456.3,435.1,435.5).ccls.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2013/01/17 14:35
S10	19	(calibrat$3 adj3 (parameter data point grid)) same ((estimat$3 measure$4 evaluat$3) adj3 (report result)) and S9	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2013/01/17 14:35
S11	1060	342/347.2,357.25,357.62.ccls.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2013/01/17 14:36
S12	0	(calibrat$3 adj3 (parameter data point grid)) same ((estimat$3 measure$4 evaluat$3) adj3 (report result)) and S11	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2013/01/17 14:36
S13	4719	702/85,94-95,150.ccls.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT;	OR	ON	2013/01/17 14:37

			IBM_TDB			
S14	35	(calibrat$3 adj3 (parameter data point grid)) same ((estimat$3 measure$4 evaluat$3) adj3 (report result)) and S13	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2013/01/17 14:37
S15	4216	340/870.04-870.05,988-989,991,995.18,995.25,423.19.ccls.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2013/01/17 14:38
S16	3	(calibrat$3 adj3 (parameter data point grid)) same ((estimat$3 measure$4 evaluat$3) adj3 (report result)) and S15	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2013/01/17 14:38
S17	763	(calibrat$3 adj3 (parameter point)) and grid and ((estimat$3 measure$4 evaluat$3) adj3 (report result)) and set and function	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2013/01/17 14:54
S18	766	(calibrat$3 adj3 (parameter point cluster)) and grid and ((estimat$3 measure$4 evaluat$3) adj3 (report result)) and set and function	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2013/01/17 15:06
S19	5	(calibrat$3 adj3 (parameter point cluster)) same grid same ((estimat$3 measure$4 evaluat$3) adj3 (report result)) same set same function	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2013/01/17 15:06
S20	24	("3087247" | "3738152" | "3769709").PN. OR ("4583298").URPN.	US-PGPUB; USPAT; USOCR	OR	OFF	2013/01/17 15:19

1/24/2013 3:17:42 PM
C:\Users\eekong\Documents\EAST\Workspaces\12026480(3).wsp

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BIB DATA SHEET

CONFIRMATION NO. 3162

SERIAL NUMBER	FILING or 371(c) DATE	CLASS	GROUP ART UNIT	ATTORNEY DOCKET NO.
12/026,480	02/05/2008 RULE	455	2641	AND01 080

APPLICANTS

Martin Alles, Vienna, VA;
John Carlson, Dulles, VA;
George Maher, Herndon, VA;
Selcuk Mazlum, Leesburg, VA;

**** CONTINUING DATA ***************************

This appln claims benefit of 60/899,379 02/05/2007

**** FOREIGN APPLICATIONS ***************************

**** IF REQUIRED, FOREIGN FILING LICENSE GRANTED ****

02/16/2008

Foreign Priority claimed	35 USC 119(a-d) conditions met	Verified and Acknowledged	Met after Allowance	STATE OR COUNTRY	SHEETS DRAWINGS	TOTAL CLAIMS	INDEPENDENT CLAIMS
☐ Yes ☑ No	☑ Yes ☐ No	/EMEM O STEPHEN/ Examiner's Signature	☐ Initials	VA	72	57	2

ADDRESS

Duane Morris LLP
505 9th Street, N.W.
Suite 1000
Washington, DC 20004
UNITED STATES

TITLE

SYSTEM AND METHOD FOR GENERATING A LOCATION ESTIMATE USING UNIFORM AND NON-UNIFORM GRID POINTS

FILING FEE RECEIVED	FEES: Authority has been given in Paper	
3270	No._____ to charge/credit DEPOSIT ACCOUNT No._____ for following:	☐ All Fees ☐ 1.16 Fees (Filing) ☐ 1.17 Fees (Processing Ext. of time) ☐ 1.18 Fees (Issue) ☐ Other _____ ☐ Credit

BIB (Rev. 05/07).

Index of Claims	Application/Control No.	Applicant(s)/Patent Under Reexamination
	12026480	ALLES ET AL.
	Examiner	**Art Unit**
	EMEM STEPHEN	2617

✓	Rejected	-	Cancelled	N	Non-Elected	A	Appeal
=	Allowed	÷	Restricted	I	Interference	O	Objected

☐ Claims renumbered in the same order as presented by applicant ☐ CPA ☐ T.D. ☐ R.1.47

CLAIM		DATE								
Final	Original	08/12/2011	01/24/2013							
1	1	✓	=							
2	2	✓	=							
3	3	✓	=							
4	4	✓	=							
5	5	✓	=							
6	6	✓	=							
7	7	✓	=							
8	8	✓	=							
9	9	✓	=							
10	10	✓	=							
11	11	O	=							
12	12	✓	=							
13	13	✓	=							
14	14	✓	=							
15	15	✓	=							
16	16	✓	=							
17	17	✓	=							
18	18	O	=							
19	19	O	=							
20	20	O	=							
21	21	O	=							
22	22	O	=							
23	23	O	=							
24	24	O	=							
25	25	O	=							
26	26	O	=							
27	27	O	=							
28	28	O	=							
29	29	✓	=							
30	30	✓	=							
31	31	✓	=							
32	32	✓	=							
33	33	✓	=							
34	34	✓	=							
35	35	✓	=							
36	36	✓	=							

Index of Claims	Application/Control No.	Applicant(s)/Patent Under Reexamination
	12026480	ALLES ET AL.
	Examiner	**Art Unit**
	EMEM STEPHEN	2617

✓	Rejected	-	Cancelled	N	Non-Elected	A	Appeal
=	Allowed	÷	Restricted	I	Interference	O	Objected

☐ Claims renumbered in the same order as presented by applicant ☐ CPA ☐ T.D. ☐ R.1.47

CLAIM		DATE								
Final	Original	08/12/2011	01/24/2013							
37	37	✓	=							
38	38	✓	=							
39	39	✓	=							
40	40	✓	=							
41	41	✓	=							
42	42	O	=							
43	43	✓	=							
44	44	✓	=							
45	45	✓	=							
46	46	✓	=							
47	47	✓	=							
48	48	✓	=							
49	49	O	=							
50	50	O	=							
51	51	O	=							
52	52	O	=							
53	53	O	=							
54	54	O	=							
55	55	✓	=							
56	56	✓	=							
57	57	✓	=							

PTO/SB/08a (01-10)
Approved for use through 07/31/2012. 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	12026480
Filing Date	2008-02-05
First Named Inventor	ALLES et al.
Art Unit	2617
Examiner Name	Emem O. Stephen
Attorney Docket Number	AND01 080

U.S.PATENTS						
Examiner Initial*	Cite No	Patent Number	Kind Code[1]	Issue Date	Name of Patentee or Applicant of cited Document	Pages,Columns,Lines where Relevant Passages or Relevant Figures Appear
	1	8155394	B2	2012-04-10	Allegra et al.	
	2	8106818	B2	2012-01-31	Bhattacharya et al.	
	3	8106817	B2	2012-01-31	Bhattacharya et al.	
	4	8068855	B2	2011-11-29	Dressler et al.	
	5	8068802	B2	2011-11-29	Bhattacharya et al.	
	6	8013785	B2	2011-09-06	Bhattacharya et al.	
	7	7899467	B2	2011-03-01	Feuerstein et al.	
	8	7848762	B2	2010-12-07	Gordon et al.	

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	First Named Inventor	ALLES et al.
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	Examiner Name	Emem O. Stephen
	Attorney Docket Number	AND01 080

	9	7796966	B2	2010-09-14	Bhattacharya et al.	
	10	7753278	B2	2010-07-13	Spain Jr. et al.	
	11	7734298	B2	2010-06-08	Bhattacharya et al.	
	12	7725111	B2	2010-05-25	Dressler et al.	
	13	7460505	B2	2008-12-02	Spain	
	14	7433695	B2	2008-10-07	Gordon et al.	
	15	7433652	B2	2008-10-07	Durgin	
	16	7383051	B2	2008-06-03	Spain Jr. et al.	
	17	7257414	B2	2007-08-14	Spain Jr. et al.	
	18	7233799	B2	2007-06-19	Spain Jr.	
	19	7167714	B2	2007-01-23	Dressler et al.	

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	20	7116987	B2	2006-10-03	Spain Jr. et al.	
	21	6944465	B2	2005-09-13	Spain et al.	
	22	6782265	B2	2004-08-24	Perez-Breva et al.	
	23	6591112	B1	2003-07-08	Siccardo et al.	
	24	6449486	B1	2002-09-10	Rao	
	25	6393294	B1	2002-05-21	Perez-Breva et al.	
	26	6281834	B1	2001-08-28	Stilp	
	27	6269246	B1	2001-07-31	Rao et al.	
	28	6115605		2000-09-05	Siccardo et al.	
	29	6108558		2000-08-22	Vanderspool II	
	30	6097709		2000-08-01	Kuwabara	

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	Examiner Name	Emem O. Stephen
	Attorney Docket Number	AND01 080

	31	7250907	B2	2007-07-31	Krumm et al.	

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U.S.PATENT APPLICATION PUBLICATIONS

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	20040203539	A1	2004-10-14	Benes et al.	

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FOREIGN PATENT DOCUMENTS

Examiner Initial*	Cite No	Foreign Document Number[3]	Country Code[2] i	Kind Code[4]	Publication Date	Name of Patentee or Applicant of cited Document	Pages,Columns,Lines where Relevant Passages or Relevant Figures Appear	T[5]
	1							☐

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NON-PATENT LITERATURE DOCUMENTS

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	RICK ROBERTS, "Project: IEEE P802.15 Working Group for Wireless Personal Area Networks (WPANS)," Harris Corporation, Melbourne Florida, October 4, 2004, pages1-11.	☐
	2	STEPHANIE BELL, "A Beginners Guide to Uncertainty of Measurement, The National Physics Laboratory of the United Kingdom of Great Britain and Northern Ireland, Teddington, Middlesex, UK, 2001, pages1-41.	☐

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	Filing Date	2008-02-05
	First Named Inventor	ALLES et al.
	Art Unit	2617
	Examiner Name	Emem O. Stephen
	Attorney Docket Number	AND01 080

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.

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	Filing Date	2008-02-05
	First Named Inventor	ALLES et al.
	Art Unit	2617
	Examiner Name	Emem O. Stephen
	Attorney Docket Number	AND01 080

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

☒ That no item of information contained in the information disclosure statement was cited in a communication from a foreign patent office in a counterpart foreign application, and, to the knowledge of the person signing the certification after making reasonable inquiry, no item of information contained in the information disclosure statement was known to any individual designated in 37 CFR 1.56(c) more than three months prior to the filing of the information disclosure statement. See 37 CFR 1.97(e)(2).

☐ 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	/Mark C. Comtois/	Date (YYYY-MM-DD)	2012-10-31
Name/Print	Mark C. Comtois	Registration Number	46285

This collection of information is required by 37 CFR 1.97 and 1.98. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 1 hour to complete, including gathering, preparing and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

Electronic Acknowledgement Receipt	
EFS ID:	14116701
Application Number:	12026480
International Application Number:	
Confirmation Number:	3162
Title of Invention:	SYSTEM AND METHOD FOR GENERATING A LOCATION ESTIMATE USING UNIFORM AND NON-UNIFORM GRID POINTS
First Named Inventor/Applicant Name:	Martin Alles
Customer Number:	79172
Filer:	Mark Charles Comtois/Nicola Kinney
Filer Authorized By:	Mark Charles Comtois
Attorney Docket Number:	AND01 080
Receipt Date:	31-OCT-2012
Filing Date:	05-FEB-2008
Time Stamp:	16:06:04
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	no

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Information Disclosure Statement (IDS) Form (SB08)	080REIDS.pdf	573926 84f1d16d14dfc5c1ac3ff9d00a4a2c944e73577c	no	6

Warnings:
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This is not an USPTO supplied IDS fillable form					
2	Non Patent Literature	beginnersguide.pdf	4056447 5bb77b5694d761cce43f8b493c501304a900025e	no	41
Warnings:					
Information:					
3	Non Patent Literature	wpans.pdf	1254875 862ea8fc8470d87a096293134dfbe7c66196dda1	no	11
Warnings:					
Information:					
			Total Files Size (in bytes):	5885248	

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If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.

National Stage of an International Application under 35 U.S.C. 371
If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.

New International Application Filed with the USPTO as a Receiving Office
If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re the Patent Application of Martin Alles, et al.

Serial No.:	12/026,480	Art Unit:	2617
Filed:	February 5, 2008	Examiner:	Emem O. Stephen

Title: SYSTEM AND METHOD FOR GENERATING A LOCATION ESTIMATE USING UNIFORM AND NON-UNIFORM GRID POINTS

Response

Commissioner for Patents
P.O. Box 1450
Alexandria, Virginia 22313-1450

Sir:

Responsive to the Office Action mailed September 20, 2011, Applicant submits the following remarks.

Applicant's **Remarks** begin on Page 2.

Remarks

Claims 1-57 are pending with entry of this paper.

Claims 1-57 stand rejected.

Applicant acknowledges the indicated allowability of Claims 11, 18-28, 42 and 49-54.

The Rejections premised upon Zeng

Claims 1-3, 6-7, 9-10, 29-34, 37-38, 40-41 and 55-57 stand improperly rejected under §102(b) as being unpatentable over Zeng. Claims 4-5, 8, 12-17, 35-36, 39 and 43-48 stand improperly rejected under §103(a) as being unpatentable over Zeng in view of other references. It appears that the rejections are premised upon both a misreading of the claimed subject matter and a misunderstanding of a fair teaching of the references of record. Applicant respectfully requests reconsideration and withdrawal of the rejection.

A. Background

The claimed subject matter is generally directed to estimating the location of a wireless mobile device using, at least in part, one or more Network Measurement Reports ("NMRs") which include calibration data for a number of locations within a geographic region. More specifically, the claimed subject matter gathers calibration data for these locations and analyzes the calibration data so that particular points (e.g., "grid points") within the geographic region can be generated and associated with a particular set or sets of calibration data from, for example, the one or more NMRs. Then, the received signal level measurements reported by the mobile device to be geolocated may be compared with the data associated with the various grid points to estimate the location of the mobile device. These grid points do not necessarily have to be part of a uniform grid and usually will not be uniformly distributed throughout the geographic region. These non-uniform grid points ("NUGs"), once determined, can be assigned geographic coordinates so that the NUGs may be used in determining the location of a mobile device exhibiting certain attributes as discussed in more detail below.

B. Zeng

In contrast, Zeng appears to be directed to an entirely different invention.

For example, Zeng determines the location of a wireless device 108 in an area 102 using a number of deployed reference devices 104 in the network. The network also includes a number of fixed calibration points 106. *See* paragraph [0015] of Zeng. Prior to determining the

location of any wireless device, a radio map is generating by performing a signal strength survey by receiving transmissions from the reference devices 104 at each of these fixed calibration points 106 using a wireless device. *See* paragraph [0018] of Zeng. Once the survey has been completed, a wireless device 108 to be located performs a scan – i.e., records signal strengths for each reference device 104. The results of this scan are compared with the radio map and a location of the wireless device 108 determined therefrom. *See* paragraph [0019] of Zeng.

C. Differences between Zeng and the claimed subject matter

For ease of reference Claim 1 is provided below in full:

> 1. A method of determining the location of a mobile device in a geographic region comprising the steps of:
>
> (a) providing calibration data for each of one or more calibration points in a geographic region, said calibration data having one or more characterizing parameters;
>
> (b) generating one or more sets of grid points for said calibration data;
>
> (c) receiving at least one network measurement report from a mobile device at an unknown location in said geographic region;
>
> (d) evaluating said at least one network measurement report with each of said sets of grid points as a function of select ones of said characterizing parameters;
>
> (e) selecting a set of grid points as a function of a predetermined criteria; and
>
> (f) determining the location of a mobile device in said geographic region as a function of said selected set of grid points.

Independent Claim 32 provides similar elements in system form. With reference to Claim 1 above, Zeng appears to provide signal strength data for calibration points in a region and determine the location of a mobile device; however, any similarities between Zeng and the claimed subject matter end there.

By way of example, Zeng fails to teach or render obvious any of element (b) – generating one or more sets of grid points for calibration data. Rather, Zeng has previously established calibration points in which a radio map is generated by performing a signal strength survey through reception (by an independent wireless device) of transmissions from reference devices 104 at each of these predetermined calibration points 106. *See* paragraph [0018] of Zeng. Thus, no grid points are generated within any geographic region in Zeng that is associated with a particular set or sets of calibration data. The claim specifically requires both calibration points

and grid points; however, the Office has not made this distinction in its rejection and has thus misread the claim and misapplied the reference of record.

Further, it appears that Zeng fails to teach or render obvious any of element (c) – receiving at least one network measurement report from a mobile device at an unknown location in the geographic region. As the Office is aware, a network measurement report (NMR) is a report that includes calibration data for a number of locations in an area. *See* [0007] of Applicant's published specification. As Zeng is completely silent regarding NMRs, the Office appears to be relying upon an inherency argument in its rejection of this element that a mere disclosure of receiving signal strength measurements from a mobile device anticipates this element. As the Office is aware, to be inherent, the Office's position must necessarily be true. This is not the case here, as a reception of RSSI values does not necessarily mean that an NMR is received; quite the contrary, RSSI values may be received for any number of reasons in any number of methods for an ultimate determination of a mobile device location, and the Office's inherency position here is both incorrect and not allowed under the MPEP. *See* MPEP § 2131. For this reason as well, Zeng fails to teach or render obvious any of element (d) – evaluating said at least one network measurement report with each of said sets of grid points as a function of select ones of said characterizing parameters. Further, as Zeng fails to disclose or teach the claimed "grid points" as discussed above, the Office's reliance upon Zeng to allegedly teach element (d) is also improper.

For several reasons, Zeng fails to teach or render obvious any of element (e) – selecting a set of grid points as a function of a predetermined criteria. As discussed above, Zeng fails to disclose or teach the claimed "grid points," and the Office's reliance upon Zeng to allegedly teach this element is improper. Further, the Office improperly relied upon paragraph [0037] of Zeng to teach this element. This paragraph is provided below in full:

> Next, a subset of S, {APV}, can be formed comprising the reference devices from which a signal was received. That is, the reference devices that were seen in the scan are in set {APV} (step 204). Then for each of the calibration points, a subset, {APC(w)}, can be formed comprising the calibration points that report an RSSI from a reference device (step 206). Next, calibration points that contain exactly the same reference devices that were seen in the current scan and represented by the set {APV} are grouped together to form a group G.sub.n (step 208). That is, G.sub.n contains calibration points where {APC (w)}={APV}.

See paragraph [0037] of Zeng. The subset S in paragraph [0037] is only a subset of the received signal strength values from the wireless device 108 when it records signal strengths for each reference device 104. *See* paragraphs [0036] and [0019] of Zeng. The results of this scan are compared with the radio map and a location of the wireless device 108 determined. *See* paragraph [0019] of Zeng. Thus, no sets of grid points (or even Zeng's calibration points) are ever selected (whether or not they are selected as a function of a predetermined criteria. Rather, Zeng selects sets or subsets of RSSI values from the mobile device 108 – nothing more. *See* paragraphs [0036]-[0037]. Finally, for the same reasons discussed above Zeng is equally silent regarding element (f) – determining the location of a mobile device in a geographic region as a function of a selected set of grid points.

Applicant submits that Zeng cannot properly be cited in a rejection of the subject matter under Sections 102 or 103 of independent Claims 1 and 32 and those claims dependent thereon. Reconsideration and withdrawal of the rejection of Claims 1-57 are respectfully requested.

Conclusion

Applicant respectfully submits that the claims are in condition for allowance and a notice to this effect is respectfully requested.

The Office is requested and hereby authorized to charge any required extension-of-time fees against Deposit Account Number 04-1679 to Duane Morris LLP.

If any point remains that is deemed best resolved through a telephonic conversation, the Office is hereby requested to contact the undersigned directly.

Respectfully submitted,

/Mark C. Comtois/

Mark C. Comtois Reg. No. 46,285
Ryan T. Hardee Reg. No. 57,515

DUANE MORRIS LLP
505 9th Street N.W., Suite 1000
Washington, D.C. 20004
Telephone: (202) 776-7800
Telecopier: (202) 776-7801

Dated: 20 December 2011

Electronic Acknowledgement Receipt	
EFS ID:	11662196
Application Number:	12026480
International Application Number:	
Confirmation Number:	3162
Title of Invention:	SYSTEM AND METHOD FOR GENERATING A LOCATION ESTIMATE USING UNIFORM AND NON-UNIFORM GRID POINTS
First Named Inventor/Applicant Name:	Martin Alles
Customer Number:	79172
Filer:	Mark Charles Comtois/laureen ponder
Filer Authorized By:	Mark Charles Comtois
Attorney Docket Number:	AND01 080
Receipt Date:	20-DEC-2011
Filing Date:	05-FEB-2008
Time Stamp:	12:30:26
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	no

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Amendment/Req. Reconsideration-After Non-Final Reject	AND01080DecAmdt.pdf	810716 2f9514d7bc391508a3f9704710804147fd936754	no	6

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New Applications Under 35 U.S.C. 111
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APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
12/026,480	02/05/2008	Martin Alles	AND01 080	3162

79172 7590 09/20/2011

Duane Morris LLP
505 9th Street, N.W.
Suite 1000
Washington, DC 20004

EXAMINER	
STEPHEN, EMEM O	
ART UNIT	PAPER NUMBER
2617	
MAIL DATE	DELIVERY MODE
09/20/2011	PAPER

Please find below and/or attached an Office communication concerning this application or proceeding.

The time period for reply, if any, is set in the attached communication.

Office Action Summary	Application No.	Applicant(s)
	12/026,480	ALLES ET AL.
	Examiner	Art Unit
	EMEM STEPHEN	2617

-- The MAILING DATE of this communication appears on the cover sheet with the correspondence address --

Period for Reply

A SHORTENED STATUTORY PERIOD FOR REPLY IS SET TO EXPIRE *3* MONTH(S) OR THIRTY (30) DAYS, WHICHEVER IS LONGER, FROM THE MAILING DATE OF THIS COMMUNICATION.

- Extensions of time may be available under the provisions of 37 CFR 1.136(a). In no event, however, may a reply be timely filed after SIX (6) MONTHS from the mailing date of this communication.
- If NO period for reply is specified above, the maximum statutory period will apply and will expire SIX (6) MONTHS from the mailing date of this communication.
- Failure to reply within the set or extended period for reply will, by statute, cause the application to become ABANDONED (35 U.S.C. § 133). Any reply received by the Office later than three months after the mailing date of this communication, even if timely filed, may reduce any earned patent term adjustment. See 37 CFR 1.704(b).

Status

1)☒ Responsive to communication(s) filed on *05 February 2008*.

2a)☐ This action is **FINAL**. 2b)☒ This action is non-final.

3)☐ Since this application is in condition for allowance except for formal matters, prosecution as to the merits is closed in accordance with the practice under *Ex parte Quayle*, 1935 C.D. 11, 453 O.G. 213.

Disposition of Claims

4)☒ Claim(s) *1-57* is/are pending in the application.

4a) Of the above claim(s) _____ is/are withdrawn from consideration.

5)☐ Claim(s) _____ is/are allowed.

6)☒ Claim(s) *1-10, 12-17, 29-41, 43-48, 55-57* is/are rejected.

7)☒ Claim(s) *11,18-28,42 and 49-54* is/are objected to.

8)☐ Claim(s) _____ are subject to restriction and/or election requirement.

Application Papers

9)☐ The specification is objected to by the Examiner.

10)☐ The drawing(s) filed on _____ is/are: a)☐ accepted or b)☐ objected to by the Examiner.

Applicant may not request that any objection to the drawing(s) be held in abeyance. See 37 CFR 1.85(a).

Replacement drawing sheet(s) including the correction is required if the drawing(s) is objected to. See 37 CFR 1.121(d).

11)☐ The oath or declaration is objected to by the Examiner. Note the attached Office Action or form PTO-152.

Priority under 35 U.S.C. § 119

12)☐ Acknowledgment is made of a claim for foreign priority under 35 U.S.C. § 119(a)-(d) or (f).

a)☐ All b)☐ Some * c)☐ None of:

1.☐ Certified copies of the priority documents have been received.

2.☐ Certified copies of the priority documents have been received in Application No. _____.

3.☐ Copies of the certified copies of the priority documents have been received in this National Stage application from the International Bureau (PCT Rule 17.2(a)).

* See the attached detailed Office action for a list of the certified copies not received.

Attachment(s)	
1) ☒ Notice of References Cited (PTO-892)	4) ☐ Interview Summary (PTO-413) Paper No(s)/Mail Date. _____ .
2) ☐ Notice of Draftsperson's Patent Drawing Review (PTO-948)	5) ☐ Notice of Informal Patent Application
3) ☒ Information Disclosure Statement(s) (PTO/SB/08) Paper No(s)/Mail Date _____.	6) ☐ Other: _____.

DETAILED ACTION

Claim Rejections - 35 USC § 102

1. The following is a quotation of the appropriate paragraphs of 35 U.S.C. 102 that form the basis for the rejections under this section made in this Office action:

> A person shall be entitled to a patent unless –(b) the invention was patented or described in a printed publication in this or a foreign country or in public use or on sale in this country, more than one year prior to the date of application for patent in the United States.

2. Claims 1-3, 6-7, 9-10, 29-34, 37-38, 40-41, and 55-57 are rejected under 35 U.S.C. 102(b) as being anticipated by US Pat. No. 6564065 B1 to Zeng et al.

Regarding claims 1, 31-32, and 57, Zeng discloses a method of determining the location of a mobile device in a geographic region (abstract, and par. 15, estimating a location of a wireless device in an area 102) comprising the steps of:

(a) providing calibration data for each of one or more calibration points in a geographic region (par. 15, a number of calibration points 106, par. 18, a survey at each calibration point), said calibration data having one or more characterizing parameters (par. 18, signal strength, RSSI, from each reference device 104 heard at that calibration point can be recorded);

(b) generating one or more sets of grid points for said calibration data (par. 18, survey can be repeated several times and the signal strength values are typically averaged. After the survey is completed, the RSSI values for each of the reference devices 104 as measured at each calibration point 106 and the coordinate of each calibration point 106 are stored at any location in the network);

(c) receiving at least one network measurement report from a mobile device at an unknown location in said geographic region (par. 19, wireless device 108 performs a scan with an unknown location);

(d) evaluating said at least one network measurement report with each of said sets of grid points as a function of select ones of said characterizing parameters (comparison of obtained information with parameters from calibration points 106);

(e) selecting a set of grid points as a function of a predetermined criteria (par. 37, for each of the calibration points, a subset, [APC(w)], can be formed comprising the calibration points that report an RSSI from a reference device (step 206). Next, calibration points that contain exactly the same reference devices that were seen in the current scan and represented by the set [APV] are grouped together to form a group G.sub.n (step 208). That is, G.sub.n contains calibration points where [APC (w)]=[APV]);

and (f) determining the location of a mobile device in said geographic region as a function of said selected set of grid points (pars. 38-39).

Regarding claims 2, and 33, Zeng discloses the method of claim 1 wherein said at least one network measurement report is a set of network measurement reports (par. 19, The signal strength for each reference device 104 as recorded by a wireless device 108 can be arranged as a set of signal strength).

Regarding claims 3, and 34, Zeng discloses the method of claim 1 wherein said predetermined criteria is selected from the group consisting of: total probability, cluster

radius, Euclidean norm, joint probability, and Mahalanobis distance (par. 22).

Regarding claims 6, and 37, Zeng discloses the method of claim 1 wherein one of said grid points is randomly located within said geographic region (see fig. 1, calibration points are randomly distributed).

Regarding claims 7, and 38, Zeng discloses the method of claim 1 wherein said calibration data comprises information from a network measurement report (par. 19).

Regarding claims 9, and 40, Zeng discloses the method of claim 1 wherein said characterizing parameter is selected from the group consisting of: signal strength for a signal transmitted by a transmitter having a known location as received by a receiver at said grid point; signal strength of a signal transmitted by a transmitter located at said grid point as received by a receiver at a known location (par. 18).

Regarding claims 10, and 41, Zeng discloses the method of claim 1 wherein the step of evaluating further comprises: (i) comparing select ones of said sets of grid points to at least one characterizing parameter of said at least one network measurement report (par. 19).

Regarding claims 29, and 55, Zeng discloses the method of claim 1 wherein the step of selecting further comprises selecting a set of grid points as a function of a

criteria of fit (fig. 2 step 206 a subset of reference devices that have an available RSSI, fig. 3 step 310, and pars. 37-38).

Regarding claims 30, and 56, Zeng discloses the method of claim 29 wherein the criteria of fit is selected from the group consisting of: total probability, cluster radius, Euclidean norm, Mahalanobis distance, distortion measure, confidence measure, and any combination thereof (par. 38 Euclidean distance formula).

Claim Rejections - 35 USC § 103

3. The following is a quotation of 35 U.S.C. 103(a) which forms the basis for all obviousness rejections set forth in this Office action:

> (a) A patent may not be obtained though the invention is not identically disclosed or described as set forth in section 102 of this title, if the differences between the subject matter sought to be patented and the prior art are such that the subject matter as a whole would have been obvious at the time the invention was made to a person having ordinary skill in the art to which said subject matter pertains. Patentability shall not be negatived by the manner in which the invention was made.

4. The factual inquiries set forth in *Graham* v. *John Deere Co.*, 383 U.S. 1, 148 USPQ 459 (1966), that are applied for establishing a background for determining obviousness under 35 U.S.C. 103(a) are summarized as follows:

1. Determining the scope and contents of the prior art.
2. Ascertaining the differences between the prior art and the claims at issue.
3. Resolving the level of ordinary skill in the pertinent art.
4. Considering objective evidence present in the application indicating obviousness or nonobviousness.

5. This application currently names joint inventors. In considering patentability of the claims under 35 U.S.C. 103(a), the examiner presumes that the subject matter of

the various claims was commonly owned at the time any inventions covered therein were made absent any evidence to the contrary. Applicant is advised of the obligation under 37 CFR 1.56 to point out the inventor and invention dates of each claim that was not commonly owned at the time a later invention was made in order for the examiner to consider the applicability of 35 U.S.C. 103(c) and potential 35 U.S.C. 102(e), (f) or (g) prior art under 35 U.S.C. 103(a).

6. Claims 4-5, 12, 35-36, and 43 are rejected under 35 U.S.C. 103(a) as being unpatentable over Zeng in view of US Pat. No. 6564065 B1 to Chang et al.

Regarding claims 4-5, 12, 35-36, and 43, Zeng discloses the method of claim 1 but fails to disclose wherein one of said grid points is located on a predetermined fixed uniform grid defined over said geographic region, and wherein one of said grid points is randomly located within said geographic region.

Cheng discloses wherein one of said grid points is located on a predetermined fixed uniform grid defined over said geographic region (grids 3-5 are fixed uniform grid), and wherein one of said grid points is randomly located within said geographic region (see fig. 2, grid points 1-2, 6 are randomly located), wherein determining a second location estimate further comprises averaging two or more first location estimates (col. 4 line 50, and col. 9 lines 35-38).

Therefore, it would have been obvious to one of ordinary skill in the art at the time of the invention to modify the invention Zeng such that one of said grid points is located on a predetermined fixed uniform grid defined over said geographic region, and wherein one of said grid points is randomly located within said geographic region as

disclosed by Cheng for the purpose of utilizing a technique that accepts and calibrate information from a variety of points to achieve a better result.

7. Claims 8, 14-17, 39, and 45-48 are rejected under 35 U.S.C. 103(a) as being unpatentable over Zeng in view of US Pat. No. 7,196,662 B2 to Misikangas et al.

Regarding claims 8, 15-17, 39, and 46-48, Zeng discloses the method of claim 1 wherein for each of select ones of said grid points the calibration data includes plural data vectors and the evaluating of said sets of grid points comprises a determination of clustering of said plural data vectors.

Misikangas discloses wherein for each of select ones of said grid points the calibration data includes plural data vectors and the evaluating of said sets of grid points comprises a determination of clustering of said plural data vectors (col, 5 lines 30-45, vectors a, b, c),

wherein determining a second location estimate further comprises weighting a first location estimate by an inverse of a distance metric (col. 5 lines 11-22, inverse distance weighting),

wherein determining a second location estimate further comprises normalizing a first location estimate by a sum of an inverse of a distance metric (col. 8 lines 9-18),

wherein determining a second location estimate further comprises weighting a first location estimate as a function of the number of reporting neighboring cells to a serving cell serving said mobile device (see fig. 1 and col. 1 lines 36-37, col. 9 lines 66-67, mobile communicates information via BS it is connected to, and col. 10 lines 12-15).

Therefore, it would have been obvious to one of ordinary skill in the art at the time of the invention to modify the invention Zeng such that for each of select ones of said grid points the calibration data includes plural data vectors and the evaluating of said sets of grid points comprises a determination of clustering of said plural data vectors for the purpose of utilizing a technique that accepts and calibrates information from plural points to achieve a better result.

8. Claims 13, and 44 are rejected under 35 U.S.C. 103(a) as being unpatentable over Zeng in view of US Pat. No. 7,167,714 B2 to Dressler et al.

Regarding claims 13, and 44, Zeng discloses the method of claim 10 however, fails to disclose further comprising the step of omitting a first location estimate having an error greater than a predetermined threshold.

Dressler discloses further comprising the step of omitting a first location estimate having an error greater than a predetermined threshold (col. 6 lines 30-36).

Therefore, it would have been obvious to one of ordinary skill in the art at the time of the invention to modify the invention of Zeng by omitting a first location estimate having an error greater than a predetermined threshold as disclosed by Dressler for the purpose of minimizing the number of errors during calibration in order to achieve desired accuracy of the location estimate.

Allowable Subject Matter

9. Claims 11, 18-28, 42, and 49-54 are objected to as being dependent upon a rejected base claim, but would be allowable if rewritten in independent form including all of the limitations of the base claim and any intervening claims.

Conclusion

Any inquiry concerning this communication or earlier communications from the examiner should be directed to EMEM STEPHEN whose telephone number is (571)272-8129. The examiner can normally be reached on 8-5 Mon-Fri..

If attempts to reach the examiner by telephone are unsuccessful, the examiner's supervisor, Charles Appiah can be reached on 571 272 7904. The fax phone number for the organization where this application or proceeding is assigned is 571-273-8300.

Information regarding the status of an application may be obtained from the Patent Application Information Retrieval (PAIR) system. Status information for published applications may be obtained from either Private PAIR or Public PAIR.

Status information for unpublished applications is available through Private PAIR only. For more information about the PAIR system, see http://pair-direct.uspto.gov. Should you have questions on access to the Private PAIR system, contact the Electronic Business Center (EBC) at 866-217-9197 (toll-free). If you would like assistance from a USPTO Customer Service Representative or access to the automated information system, call 800-786-9199 (IN USA OR CANADA) or 571-272-1000.

/E. S./
Examiner, Art Unit 2617

/Charles N. Appiah/
Supervisory Patent Examiner, Art Unit 2617

Search Notes	Application/Control No.	Applicant(s)/Patent Under Reexamination
	12026480	ALLES ET AL.
	Examiner	Art Unit
	EMEM STEPHEN	2617

SEARCHED			
Class	Subclass	Date	Examiner
455	422.1,423,425,433,404.2,456.1-456.3, 435.1-435.5		
340	870.04-870.05,988-989, 991,995.18,995.25,423.19		
342	357.2-357.25,357.62		
702	85,94-95,150		

SEARCH NOTES		
Search Notes	Date	Examiner
east search	8/12/2011	es

INTERFERENCE SEARCH			
Class	Subclass	Date	Examiner

Notice of References Cited	Application/Control No. 12/026,480	Applicant(s)/Patent Under Reexamination ALLES ET AL.	
	Examiner EMEM STEPHEN	Art Unit 2617	Page 1 of 1

U.S. PATENT DOCUMENTS

*		Document Number Country Code-Number-Kind Code	Date MM-YYYY	Name	Classification
*	A	US-6,564,065	05-2003	Chang et al.	455/457
*	B	US-7,167,714	01-2007	Dressler et al.	455/456.1
*	C	US-2005/0266855	12-2005	Zeng et al.	455/456.1
*	D	US-7,196,662	03-2007	Misikangas et al.	342/451
	E	US-			
	F	US-			
	G	US-			
	H	US-			
	I	US-			
	J	US-			
	K	US-			
	L	US-			
	M	US-			

FOREIGN PATENT DOCUMENTS

*		Document Number Country Code-Number-Kind Code	Date MM-YYYY	Country	Name	Classification
	N					
	O					
	P					
	Q					
	R					
	S					
	T					

NON-PATENT DOCUMENTS

*		Include as applicable: Author, Title Date, Publisher, Edition or Volume, Pertinent Pages)
	U	
	V	
	W	
	X	

*A copy of this reference is not being furnished with this Office action. (See MPEP § 707.05(a).)
Dates in MM-YYYY format are publication dates. Classifications may be US or foreign.

Index of Claims	Application/Control No.	Applicant(s)/Patent Under Reexamination
	12026480	ALLES ET AL.
	Examiner	Art Unit
	EMEM STEPHEN	2617

✓	Rejected	-	Cancelled	N	Non-Elected	A	Appeal
=	Allowed	÷	Restricted	I	Interference	O	Objected

☐ Claims renumbered in the same order as presented by applicant ☐ CPA ☐ T.D. ☐ R.1.47

CLAIM		DATE								
Final	Original	08/12/2011								
	1	✓								
	2	✓								
	3	✓								
	4	✓								
	5	✓								
	6	✓								
	7	✓								
	8	✓								
	9	✓								
	10	✓								
	11	O								
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	13	✓								
	14	✓								
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	16	✓								
	17	✓								
	18	O								
	19	O								
	20	O								
	21	O								
	22	O								
	23	O								
	24	O								
	25	O								
	26	O								
	27	O								
	28	O								
	29	✓								
	30	✓								
	31	✓								
	32	✓								
	33	✓								
	34	✓								
	35	✓								
	36	✓								

Index of Claims	Application/Control No.	Applicant(s)/Patent Under Reexamination
	12026480	ALLES ET AL.
	Examiner	**Art Unit**
	EMEM STEPHEN	2617

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=	Allowed	÷	Restricted	I	Interference	O	Objected

☐ Claims renumbered in the same order as presented by applicant ☐ CPA ☐ T.D. ☐ R.1.47

CLAIM		DATE								
Final	Original	08/12/2011								
	37	✓								
	38	✓								
	39	✓								
	40	✓								
	41	✓								
	42	O								
	43	✓								
	44	✓								
	45	✓								
	46	✓								
	47	✓								
	48	✓								
	49	O								
	50	O								
	51	O								
	52	O								
	53	O								
	54	O								
	55	✓								
	56	✓								
	57	✓								

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

PTO/SB/08a (01-10)
Approved for use through 07/31/2012. 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	12026480
Filing Date	2008-02-05
First Named Inventor	Martin Alles et al.
Art Unit	2617
Examiner Name	Unassigned
Attorney Docket Number	AND01 080

U.S.PATENTS

Examiner Initial*	Cite No	Patent Number	Kind Code[1]	Issue Date	Name of Patentee or Applicant of cited Document	Pages,Columns,Lines where Relevant Passages or Relevant Figures Appear
/E.S./	1	5960341	A	1999-09-28	LeBlanc	

If you wish to add additional U.S. Patent citation information please click the Add button.

U.S.PATENT APPLICATION PUBLICATIONS

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
/E.S./	1	20050040968	A1	2005-02-24	Damarla et al.	
/E.S./	2	20050266855	A1	2005-12-01	Zeng	

If you wish to add additional U.S. Published Application citation information please click the Add button.

FOREIGN PATENT DOCUMENTS

Examiner Initial*	Cite No	Foreign Document Number[3]	Country Code[2] i	Kind Code[4]	Publication Date	Name of Patentee or Applicant of cited Document	Pages,Columns,Lines where Relevant Passages or Relevant Figures Appear	T[5]
/E.S./	1	1471688	EP	A2	2004-10-27	AT&T		☐
/E.S./	2	02082832	WO	A	2004-10-27	MacDonald		☐

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)		
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	First Named Inventor	Martin Alles et al.
	Art Unit	2617
	Examiner Name	Unassigned
	Attorney Docket Number	AND01 080

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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		☐

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Examiner Signature	/Emem Stephen/ (09/13/2011)	Date Considered	

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CONSIDERED: /E.S./ (09/13/2011)

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)		
	Application Number	12026480
	Filing Date	2008-02-05
	First Named Inventor	ALLES et al.
	Art Unit	2617
	Examiner Name	STEPHEN, EMEM O
	Attorney Docket Number	AND01 080

U.S.PATENTS

Examiner Initial*	Cite No	Patent Number	Kind Code[1]	Issue Date	Name of Patentee or Applicant of cited Document	Pages,Columns,Lines where Relevant Passages or Relevant Figures Appear
	1					

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U.S.PATENT APPLICATION PUBLICATIONS

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
/E.S./	1	20050078033	A1	2005-04-14	Tamaki et al.	
	2					

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NON-PATENT LITERATURE DOCUMENTS

Receipt date: 10/25/2010	Application Number	12026480 12026480 - GAU: 2617
INFORMATION DISCLOSURE STATEMENT BY APPLICANT	Filing Date	2008-02-05
	First Named Inventor	ALLES et al.
(Not for submission under 37 CFR 1.99)	Art Unit	2617
	Examiner Name	STEPHEN, EMEM O
	Attorney Docket Number	AND01 080

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]
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CONSIDERED: /E.S./ (09/13/2011)

PTO/SB/08a (08-07)
Approved for use through 09/30/2007. OMB 0651-0031
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U.S.PATENTS

Examiner Initial*	Cite No	Patent Number	Kind Code[1]	Issue Date	Name of Patentee or Applicant of cited Document	Pages,Columns,Lines where Relevant Passages or Relevant Figures Appear
/E.S./	1	6871077	B2	2005-03-22	Kennedy	

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U.S.PATENT APPLICATION PUBLICATIONS

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
/E.S./	1	20060030333	A1	2006-02-09	Ward, et al.	
/E.S./	2	20050243936	A1	2005-11-03	Agrawala, et al.	
/E.S./	3	20060240843	A1	2006-10-26	Spain, et al.	

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Examiner Initial*	Cite No	Foreign Document Number[3]	Country Code[2]	Kind Code[4]	Publication Date	Name of Patentee or Applicant of cited Document	Pages,Columns,Lines where Relevant Passages or Relevant Figures Appear	T[5]
/E.S./	1	2000034799	WO	A1	2000-06-15	Hilsenrath, et al.		☐

Receipt date: 09/25/2008	Application Number	12026480	12026480 - GAU: 2617
INFORMATION DISCLOSURE STATEMENT BY APPLICANT (**Not for submission under 37 CFR 1.99**)	Filing Date	2008-02-05	
	First Named Inventor	Martin ALLES, et al.	
	Art Unit	2617	
	Examiner Name	Unassigned	
	Attorney Docket Number	AND01 080	

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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		☐

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

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Examiner Signature	/Emem Stephen/ (09/13/2011)	Date Considered	

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CONSIDERED: /E.S./ (09/13/2011)

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

PTO/SB/08a (01-10)
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INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)		
	Application Number	12026480
	Filing Date	2008-02-05
	First Named Inventor	ALLES et al.
	Art Unit	2617
	Examiner Name	STEPHEN, EMEM O
	Attorney Docket Number	AND01 080

U.S.PATENTS

Examiner Initial*	Cite No	Patent Number	Kind Code[1]	Issue Date	Name of Patentee or Applicant of cited Document	Pages,Columns,Lines where Relevant Passages or Relevant Figures Appear
	1					

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U.S.PATENT APPLICATION PUBLICATIONS

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	20050078033	A1	2005-04-14	Tamaki et al.	
	2					

If you wish to add additional U.S. Published Application citation information please click the Add button.

FOREIGN PATENT DOCUMENTS

Examiner Initial*	Cite No	Foreign Document Number[3]	Country Code[2] i	Kind Code[4]	Publication Date	Name of Patentee or Applicant of cited Document	Pages,Columns,Lines where Relevant Passages or Relevant Figures Appear	T[5]
	1							☐

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NON-PATENT LITERATURE DOCUMENTS

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)		
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	First Named Inventor	ALLES et al.
	Art Unit	2617
	Examiner Name	STEPHEN, EMEM O
	Attorney Docket Number	AND01 080

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		☐

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

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.

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	Filing Date	2008-02-05
	First Named Inventor	ALLES et al.
	Art Unit	2617
	Examiner Name	STEPHEN, EMEM O
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CERTIFICATION STATEMENT

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

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OR

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☐ See attached certification statement.

☐ Fee set forth in 37 CFR 1.17 (p) has been submitted herewith.

☐ None

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	/Mark C. Comtois/	Date (YYYY-MM-DD)	2010-10-25
Name/Print	Mark C. Comtois	Registration Number	46,285

This collection of information is required by 37 CFR 1.97 and 1.98. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 1 hour to complete, including gathering, preparing and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

Electronic Acknowledgement Receipt	
EFS ID:	8698779
Application Number:	12026480
International Application Number:	
Confirmation Number:	3162
Title of Invention:	SYSTEM AND METHOD FOR GENERATING A LOCATION ESTIMATE USING UNIFORM AND NON-UNIFORM GRID POINTS
First Named Inventor/Applicant Name:	Martin Alles
Customer Number:	79172
Filer:	Mark Charles Comtois/nicola kinney
Filer Authorized By:	Mark Charles Comtois
Attorney Docket Number:	AND01 080
Receipt Date:	25-OCT-2010
Filing Date:	05-FEB-2008
Time Stamp:	19:51:34
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	no

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Information Disclosure Statement (IDS) Filed (SB/08)	080ids.pdf	493564 58338e430b793fbd76d3a4974728507a4bfed9dc	no	3

Warnings:
Information:

This is not an USPTO supplied IDS fillable form	
Total Files Size (in bytes):	493564

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New Applications Under 35 U.S.C. 111
If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.

National Stage of an International Application under 35 U.S.C. 371
If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.

New International Application Filed with the USPTO as a Receiving Office
If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

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

PTO/SB/08a (01-10)
Approved for use through 07/31/2012. 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	12026480
	Filing Date	2008-02-05
	First Named Inventor	Martin Alles et al.
	Art Unit	2617
	Examiner Name	Unassigned
	Attorney Docket Number	AND01 080

U.S.PATENTS						
Examiner Initial*	Cite No	Patent Number	Kind Code[1]	Issue Date	Name of Patentee or Applicant of cited Document	Pages,Columns,Lines where Relevant Passages or Relevant Figures Appear
	1	5960341	A	1999-09-28	LeBlanc	
If you wish to add additional U.S. Patent citation information please click the Add button.						

U.S.PATENT APPLICATION PUBLICATIONS						
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	20050040968	A1	2005-02-24	Damarla et al.	
	2	20050266855	A1	2005-12-01	Zeng	
If you wish to add additional U.S. Published Application citation information please click the Add button.						

FOREIGN PATENT DOCUMENTS								
Examiner Initial*	Cite No	Foreign Document Number[3]	Country Code[2] i	Kind Code[4]	Publication Date	Name of Patentee or Applicant of cited Document	Pages,Columns,Lines where Relevant Passages or Relevant Figures Appear	T[5]
	1	1471688	EP	A2	2004-10-27	AT&T		☐
	2	02082832	WO	A	2004-10-27	MacDonald		☐

EFS Web 2.1.17

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)		
	Application Number	12026480
	Filing Date	2008-02-05
	First Named Inventor	Martin Alles et al.
	Art Unit	2617
	Examiner Name	Unassigned
	Attorney Docket Number	AND01 080

If you wish to add additional Foreign Patent Document citation information please click the Add button

NON-PATENT LITERATURE DOCUMENTS

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		☐

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

EXAMINER SIGNATURE

Examiner Signature		Date Considered	

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[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	12026480
	Filing Date	2008-02-05
	First Named Inventor	Martin Alles et al.
	Art Unit	2617
	Examiner Name	Unassigned
	Attorney Docket Number	AND01 080

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OR

☐ That no item of information contained in the information disclosure statement was cited in a communication from a foreign patent office in a counterpart foreign application, and, to the knowledge of the person signing the certification after making reasonable inquiry, no item of information contained in the information disclosure statement was known to any individual designated in 37 CFR 1.56(c) more than three months prior to the filing of the information disclosure statement. See 37 CFR 1.97(e)(2).

☐ See attached certification statement.

☐ Fee set forth in 37 CFR 1.17 (p) has been submitted herewith.

☒ None

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	/mcc/	Date (YYYY-MM-DD)	2010-03-15
Name/Print	Mark C. Comtois	Registration Number	46,285

This collection of information is required by 37 CFR 1.97 and 1.98. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 1 hour to complete, including gathering, preparing and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

Electronic Acknowledgement Receipt	
EFS ID:	7216191
Application Number:	12026480
International Application Number:	
Confirmation Number:	3162
Title of Invention:	SYSTEM AND METHOD FOR GENERATING A LOCATION ESTIMATE USING UNIFORM AND NON-UNIFORM GRID POINTS
First Named Inventor/Applicant Name:	Martin Alles
Customer Number:	79172
Filer:	Mark Charles Comtois/Laureen Ponder
Filer Authorized By:	Mark Charles Comtois
Attorney Docket Number:	AND01 080
Receipt Date:	16-MAR-2010
Filing Date:	05-FEB-2008
Time Stamp:	12:46:34
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	no

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1		AND0180IDS.pdf	481440 52118d9960ee6ca9bdd6fc7e1aa6fcd283f6e735	yes	3

	Multipart Description/PDF files in .zip description		
	Document Description	**Start**	**End**
	Information Disclosure Statement (IDS) Filed (SB/08)	1	2
	Transmittal Letter	3	3

Warnings:					
Information:					
2	NPL Documents	AND0180SCHRPT.pdf	388165 9255ca9de1f07b52e8868dd258eb7f146c0d8958	no	3
Warnings:					
Information:					
		Total Files Size (in bytes):	869605		

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New Applications Under 35 U.S.C. 111
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National Stage of an International Application under 35 U.S.C. 371
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New International Application Filed with the USPTO as a Receiving Office
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ATTORNEY DOCKET NO. AND01 080
1485 US

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re the Patent Application of : Martin ALLES, et al.

Confirmation No.: 3162

Serial No.: 12/026,480 Art. Unit: Unassigned

Filed: February 5, 2008 Examiner: Unassigned

Title: SYSTEM AND METHOD FOR GENERATING A LOCATION ESTIMATE USING UNIFORM AND NON-UNIFORM GRID POINTS

STATUS INQUIRY

Applicant respectfully inquires as to the status of the above-referenced application. The application was filed February 5, 2008, and its last known status was an Information Disclosure Statement filed on September 25, 2008. To date, no further communication has been received on this application.

The Commissioner is hereby authorized to charge payment of any additional fees associated with this communication or credit any overpayment to **Deposit Account No. 04-1679**.

Respectfully submitted,

/mcc/
Mark C. Comtois Reg. No. 46,285

DUANE MORRIS LLP
505 9th Street, N.W., Suite 1000
Washington, D.C. 20004
Telephone: (202) 776-7800
Facsimile: (202) 776-7801
Dated: August 11, 2009

DM2/2020560.v1

Electronic Acknowledgement Receipt	
EFS ID:	5869437
Application Number:	12026480
International Application Number:	
Confirmation Number:	3162
Title of Invention:	SYSTEM AND METHOD FOR GENERATING A LOCATION ESTIMATE USING UNIFORM AND NON-UNIFORM GRID POINTS
First Named Inventor/Applicant Name:	Martin Alles
Customer Number:	79172
Filer:	Mark Charles Comtois/Jacquetta McBee
Filer Authorized By:	Mark Charles Comtois
Attorney Docket Number:	AND01 080
Receipt Date:	11-AUG-2009
Filing Date:	05-FEB-2008
Time Stamp:	17:51:22
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	no

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Request for status of Application	AND01_080_STATUSINQUIRY.pdf	113410 da346e20f670b36b4cffe942fcad33260cbbb0f9	no	1

Warnings:
Information:

Total Files Size (in bytes):	113410

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ATTORNEY DOCKET NO. AND01 080

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re the Patent Application of Martin ALLES, et al.

Serial No.: 12/026,480 Art Unit: 2617

Filed: 02 February 2008 Examiner: Unassigned

Title: **SYSTEM AND METHOD FOR GENERATING A LOCATION ESTIMATE USING UNIFORM AND NON-UNIFORM GRID POINTS**

TRANSMITTAL

Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Sir:

Transmitted herewith is an Information Disclosure Statement pursuant to 37 CFR §1.56 in connection with the above-identified application .

[X] No fee required:

[ ] Filed within three months of filing application, or

[ ] Certification made.

[X] Filed prior to first Office Action.

No fees are believed to be due with this submission. However, should any fees be required, the Commissioner is hereby authorized to charge such required fees to **Deposit Account No. 04-1679.**

Respectfully submitted,

/mcc/

Mark C. Comtois Reg. No. 46,285

DUANE MORRIS LLP
505 9th Street, N.W., Suite 1000
Washington, D.C. 200044
Telephone: (202) 776-7800
Facsimile: (202) 776-7801
Dated: September 25, 2008

DM2/1582608.v1

PTO/SB/08a (05-07)
Approved for use through 09/30/2007. OMB 0651-0031
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
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	Filing Date	2008-02-05
	First Named Inventor	Martin ALLES, et al.
	Art Unit	2617
	Examiner Name	Unassigned
	Attorney Docket Number	AND01 080

U.S.PATENTS

Examiner Initial*	Cite No	Patent Number	Kind Code[1]	Issue Date	Name of Patentee or Applicant of cited Document	Pages,Columns,Lines where Relevant Passages or Relevant Figures Appear
	1	6871077	B2	2005-03-22	Kennedy	

If you wish to add additional U.S. Patent citation information please click the Add button.

U.S.PATENT APPLICATION PUBLICATIONS

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	20060030333	A1	2006-02-09	Ward, et al.	
	2	20050243936	A1	2005-11-03	Agrawala, et al.	
	3	20060240843	A1	2006-10-26	Spain, et al.	

If you wish to add additional U.S. Published Application citation information please click the Add button.

FOREIGN PATENT DOCUMENTS

Examiner Initial*	Cite No	Foreign Document Number[3]	Country Code[2]	Kind Code[4]	Publication Date	Name of Patentee or Applicant of cited Document	Pages,Columns,Lines where Relevant Passages or Relevant Figures Appear	T[5]
	1	2000034799	WO	A1	2000-06-15	Hilsenrath, et al.		☐

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	Filing Date	2008-02-05
	First Named Inventor	Martin ALLES, et al.
	Art Unit	2617
	Examiner Name	Unassigned
	Attorney Docket Number	AND01 080

If you wish to add additional Foreign Patent Document citation information please click the Add button

NON-PATENT LITERATURE DOCUMENTS

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		☐

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Examiner Signature		Date Considered	

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☐ Fee set forth in 37 CFR 1.17 (p) has been submitted herewith.

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Signature	/mcc/	Date (YYYY-MM-DD)	2008-09-25
Name/Print	Mark C. Comtois	Registration Number	46,285

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PCT WORLD INTELLECTUAL PROPERTY ORGANIZATION
International Bureau

INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 7 : G01S 3/02

A1

(11) International Publication Number: WO 00/34799

(43) International Publication Date: 15 June 2000 (15.06.00)

(21) International Application Number: PCT/US99/24493

(22) International Filing Date: 19 October 1999 (19.10.99)

(30) Priority Data:

09/205,557	4 December 1998 (04.12.98)	US
09/231,256	15 January 1999 (15.01.99)	US
09/275,655	24 March 1999 (24.03.99)	US

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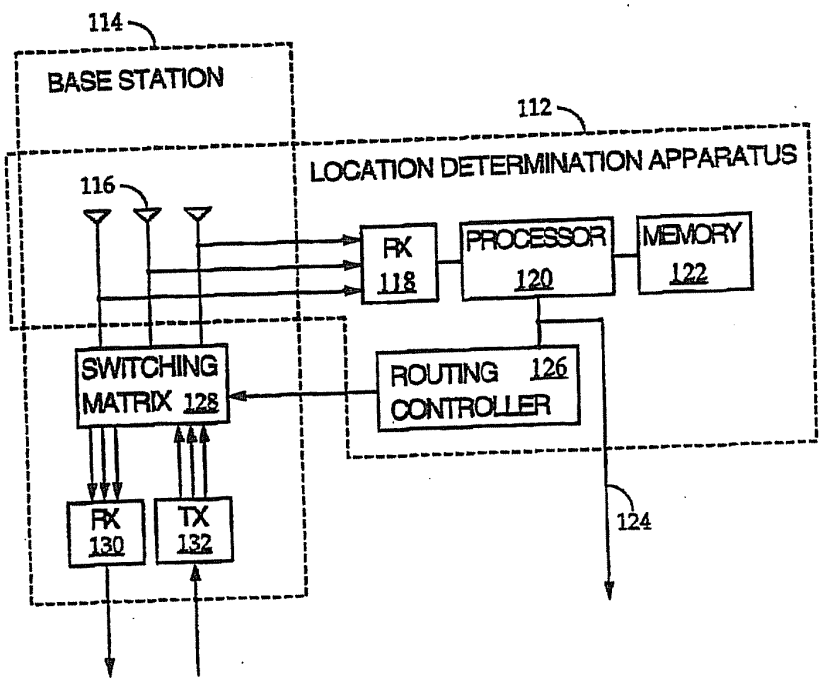
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(54) Title: WIRELESS LOCATION DETERMINATION USING SPATIAL SIGNATURE INFORMATION

(57) Abstract

A method for determining locations of mobile transmitters in a wireless communication system calculates a signature from signals received at an antenna array from the mobile, and matches the signature with calibrated signatures stored in a database to estimate the location of the mobile. The signature contains information characterizing the spatial channel between the mobile and the antenna array. An apparatus (112) implementing the method comprises an antenna array (116) and multi–channel receiver (118) for coherently receiving multi–dimensional signal vectors from a mobile transmitter. A processor (120) calculates a signal signature from the received signal vectors, which compared with calibrated signatures stored in a memory (122) to identify calibrated signatures that are similar to the calculated signature, and which corresponds to the likely locations of the mobile transmitter. Thus, the location of the transmitter can be accurately determined from the signals received at a single base station, even in a severe multipath environment.



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PCT PATENT APPLICATION OF U.S. WIRELESS CORPORATION

WIRELESS LOCATION DETERMINATION USING SPATIAL SIGNATURE INFORMATION

FIELD OF THE INVENTION

This invention relates generally to methods for determining the location of a radio transmitter. More particularly, it relates to methods for determining the location of cellular telephones, pagers, and other portable transmitters operating in urban environments characterized by a high degree of multipath.

BACKGROUND OF THE INVENTION

A long standing problem in radio communications is accurately determining the location of a mobile radio transmitter. Precise location information in a cellular telephone network is desirable for various reasons that have been recognized in the prior art. For example, cellular location information can be used to assist emergency dispatching, tracking unauthorized cell phone usage, and tracking or locating fleets of vehicles. Other applications include locating lost or stolen vehicles, assisting lost motorists, and providing various location-based services. These applications have yet to be realized, however, because they require accurate location information and no suitable method of providing such information has yet been developed. Generally, prior art location determination techniques fail for one or more of the following reasons: (1) they fail to operate in urban environments where multipath effects are severe, (2) they do not operate if fewer than three base stations are in range of the signal from a transmitter, (3) they do not provide location information with sufficient accuracy, precision, or confidence, and (4) they require extensive modifications to the mobile transmitter, to the communication system base stations, or to both.

Multipath is perhaps the most fundamental obstacle to prior art methods of solving the location finding problem. Multipath is typically caused by the reflection of signals from objects in the environment, such as buildings, hills, and other structures. A signal transmitted from a cellular phone will often be reflected from these structures, resulting in

multipath signals arriving at a base station in addition to a direct path signal. The angles of arrival of the multipath signals are usually different from the angle of arrival of the direct path signal. In addition, because the path lengths of the multipath signals differ from those of the direct path signal, the multipath signals and the direct path signal have different times of arrival. Moreover, in an urban environment where severe multipath is present, sometimes no direct path exists at all and the base station receives only the multipath signals. Conventional location determination techniques, however, are based on angle-of-arrival measurements or time-of-arrival measurements. As a result, they suffer significantly from the effects of multipath, and elaborate techniques are used in attempts to mitigate the multipath effects. For example, the prior art teaches signal averaging techniques, spread spectrum or frequency hopping techniques, and techniques for multipath identification and removal. In cases of severe multipath, however, there often is no direct path signal at all. In such cases, these approaches fail. Moreover, averaging techniques are based on assumptions about the distribution of multipath that are not generally valid, especially in severe multipath environments. Even in cases where such assumptions do hold, these averaging techniques do not yield accurate position information. The prior art approaches, therefore, operate only when multipath effects are minimal, and fail to provide reliable and accurate location information in urban environments where multipath effects are severe.

SUMMARY OF THE INVENTION

In contrast with all prior art location finding methods which attempt to eliminate or avoid multipath signals and their effects, the present invention advantageously uses multipath signals in order to accurately determine a transmitter's location. Surprisingly, in contrast to other techniques of location finding, the accuracy of the present technique is improved in severe multipath environments. Moreover, the present invention provides a method of location finding which, in contrast to other methods, can accurately determine a location from a single base station. This feature of the invention also distinguishes it from prior techniques which either require multiple base stations or provide only very inaccurate or imprecise location information. In addition, the present location determination technique does not require any modification to the transmitter, or to the existing base stations of the wireless communication system. The invention, therefore, provides a unique solution to the location finding problem which has heretofore remained unsolved.

According to the principles of the present invention, an antenna array of a location-finding apparatus coherently receives multi-dimensional signal vectors from a mobile transmitter. The specific technique for acquiring the signal vectors will depend on the wireless communication standard used by the transmitter. Once the signals are acquired, the apparatus

then calculates a transmitter signal signature from the received signal vectors. In general, a signal signature is defined as any location-dependent feature derived from the signals received at the antenna array from a transmitter at a given location. For example, the signature may be derived from various combinations of signal amplitude, phase, delay, direction, and polarization information derived from the signal vectors. Preferably, the signature is substantially invariant with respect to all variables unrelated to transmitter position, such as noise and interference. In a preferred embodiment, the signal signature comprises signal multipath characteristics of a spatial channel between the mobile and the location-finding apparatus. Most preferably, the signature comprises a signal covariance matrix formed from the signal vectors, or a subspace of the matrix spanned by its dominant eigenvectors.

The transmitter signal signature, together with calibrated signatures and corresponding calibrated locations are then used to determine one or more likely locations of the transmitter, for example, by calculating a similarity between the transmitter signature and each of the calibrated signatures. The likely locations correspond to the calibrated signatures that are most similar to the transmitter signature. In this manner, the location of the transmitter can be accurately determined from signals received at a single base station, even in a severe multipath environment. More sophisticated matching techniques can be used to reduce location ambiguity and provide more accurate location estimates. In addition, although the present techniques do not require more than one base station for accurate location determination, in the event that signatures from multiple base stations are available, they can be combined to increase the accuracy and confidence of the location estimates.

The calibrated signal signatures and corresponding locations are determined by a calibration procedure in which known locations are associated with transmitter signal signatures, preferably using a calibration transmitter equipped with a global positioning system (GPS) receiver. The calibrated signature and location information can then be collected, processed, organized, and stored in a database for subsequent use in real-time location determination.

The techniques of the present invention have various useful applications. For example, the database of signal signatures and locations can be used to derive antenna calibration information. This information, in turn, can be used to enhance location determination. In another useful application, the signature of a transmitter can be used to estimate its velocity. This velocity information, in turn, can be used to improve signal acquisition and signature determination, as well as location determination. The accurate location information provided by the present invention has a broad range of useful applications. To name just a few, the location information can be used to provide location-based services and information to mobile users, it can be used to track or locate people, vehicles, or other valuable objects that

may be missing, stolen, or in need of attention or assistance, and it can be used to provide to a wireless communications system operator real-time location-enhanced information that can assist in various types of network enhancement, diagnosis, planning, evaluation, analysis, or management.

DESCRIPTION OF THE DRAWINGS

FIGS. 1A, 1B, and 1C illustrate three levels of integration between an existing base station and a location determination apparatus (LDA) of the present invention. FIG. 1A shows an LDA closely integrated with a base station, FIG. 1B shows an LDA partially integrated with a base station, and FIG. 1C shows a stand-alone implementation of an LDA not directly connected to the base station.FIG. 2 is a block diagram of an LDA integrated with a base station, corresponding to the implementation shown in FIG. 1A.

FIG. 3 illustrates a spatial channel that is characterized by multipath propagation effects. According to the present invention, this spatial channel information measured and used to construct a signature that is highly correlated with the mobile position. Comparing the signature with calibrated signatures associated with known locations, the location of the mobile is estimated.

FIG. 4 is a block diagram of an LDA according to an embodiment of the present invention suited for a CDMA wireless system.

FIG. 5 illustrates the temporal structure of a CDMA signal according to the IS-95 standard. In particular, the CDMA signal is composed of a sequence of temporal frames, each having a duration of 20 ms. Each frame, in turn, is divided into 16 power control groups, each having a 1.25 ms duration.

FIG. 6 is a block diagram of an efficient receiver architecture according to an embodiment of the present invention suited for a CDMA wireless system.

FIGS. 7A, 7B, 7C, and 7D illustrate signal sampling schemes employed in a preferred embodiment of the present invention. FIG. 7A illustrates how approximately 100 signal samples are taken during a 1 ms sampling interval. FIG. 7B illustrates how a batch of signal samples from a given mobile device is collected once every 50 ms. FIG. 7C illustrates how batch covariance matrices for a given mobile device are collected over the course of a few seconds. FIG. 7D illustrates how a sequence of signal covariance matrices is generated over the course of time, with one covariance matrix added to the sequence every 5 s.

FIGS. 8A and 8B are schematic diagrams of geographical bins and sub-bins used in a calibration table compression technique of the present invention. The sub-bins shown

are squares about 10 m across, and the bins are squares about 30 m across. The locations of raw data points are shown in the figures as empty circles.

FIG. 9 is an illustration of the service region of an LDA containing a set of calibrated locations, shown in the figure as circled 'x' marks. The figure also shows an angular sector of the service region centered around an angle θ having an angular width $\Delta\theta$. According to one aspect of the invention, the calibrated signatures in the sector are used to calculate an array calibration vector.

FIG. 10 is a graph of a function $D(\mathbf{S},\mathbf{S}_k)$ with respect to calibrated locations k. The value of the function at a given location k is a measure of the similarity between a measured signature $\mathbf{S}$ and a calibrated signature $\mathbf{S}_k$. The graph also represents a "spectrum" of the signature $\mathbf{S}$ with respect to the entire set of calibrated signatures $\mathbf{S}_1,\ldots,\mathbf{S}_N$. According to one matching technique, the likely locations of the mobile having signature $\mathbf{S}$ are the locations k(1),k(2),...,k(M) such that $D(\mathbf{S},\mathbf{S}_{k(j)}) > h$ for j=1,...M,, where h is a predetermined threshold value. This subset of points is illustrated in the figure as those points above the dotted line corresponding to the value of h.

FIG. 11 shows the graph for a measured signal spectrum $\mathbf{w}$ together with the graphs for two calibrated spectra $\mathbf{w}_{k(1)}$ and $\mathbf{w}_{k(2)}$. According to a preferred matching technique, the likely locations of a mobile having spectrum $\mathbf{w}$ are found by comparing $\mathbf{w}$ with the calibrated spectra $\mathbf{w}_1,\ldots,\mathbf{w}_N$. For example, as is evident from the figure, the spectrum $\mathbf{w}_{k(2)}$ is more similar to the spectrum $\mathbf{w}$ than to the spectrum $\mathbf{w}_{k(1)}$. Thus, location k(2) is more likely than location k(1).

FIG. 12 is a graphical representation of mobile "tracks" according to a preferred ambiguity reduction technique. The tracks are illustrated in the figure by solid curves. The tracks, which represent past hypothetical trajectories derived from sets of likely locations collected over time, are used to predict a set of next points, shown as empty circles. Ambiguities in a current set of likely locations can be reduced by reducing the probabilities for locations that are not close to the predicted next points.

FIG. 13 illustrates a system used to implement a technique for resolving ambiguity by combining sets of likely locations obtained from multiple LDAs. A central hub collects the location information over communication lines. Because the location information is independently derived at separate LDAs, it can be combined to reduce ambiguity and increase confidence.

FIG. 14 is a schematic diagram of a hierarchical tree structure used in a technique to improve the computational efficiency of the real-time signature matching. The tree structure is composed of a number of nodes, shown as circles in the figure. Each calibrated location is assigned to at least one bottom node. The nodes higher in the tree contain the union of all nodes connected downward from them. In the search of similar

calibrated signatures, this tree can be used to eliminate a significant amount of computation.

DETAILED DESCRIPTION

Although the following detailed description contains many specifics for the purposes of illustration, anyone of ordinary skill in the art will appreciate that many variations and alterations to the following details are within the scope of the invention. Accordingly, the following preferred embodiment of the invention is set forth without any loss of generality to, and without imposing limitations upon, the claimed invention.

System Architecture

NETWORK OVERVIEW

A preferred embodiment of the present invention is designed to operate in the context of one or more wireless communication systems providing services to cellular telephones, pagers, wireless modems, and other portable communication devices. Each communication system includes a number of base stations, each designed to communicate with the portable devices in its geographical area, or cell. Downlink radio frequency (RF) signals are transmitted from the base station to the portable devices, and uplink RF signals are transmitted from the portable devices to the base station. A conventional base station typically has a set of six directional antennas for transmitting the downlink signals and receiving the uplink signals. These six antennas are normally grouped into three pairs, where each pair is designed to serve a 120-degree sector of the cell. When communicating with a portable device in a particular sector, only one of the six antennas is normally used. In particular, the antenna used for a particular mobile device is dynamically selected to provide the best signal. If the quality of the communication link between a base station and a mobile device degrades, the communication system typically attempts to hand-off the link to another base station that can provide a higher quality link. In this manner, a portable device moving throughout the communication system's network of cells can receive continuous service. The location of a particular device in these conventional systems is known only approximately. The network knows which base station is serving the mobile device, and can sometimes determine which antenna is being used for communication with the device. Using this information, however, the location of a user can be narrowed down to an area of several square kilometers, at best.

LOCATION FINDING APPARATUS

A location determination apparatus (LDA) according to the present invention is used to provide more accurate and precise location information of mobile devices. As illustrated in FIGS. 1A, 1B, and 1C, the LDA may be integrated partly or completely with an existing base station of a communication system, or may be a separate stand-alone apparatus operating idependent of other communication systems. For example, FIG. 1A shows and LDA 100 integrated with a base station 102. In this integrated implementation, the LFA makes use of the existing antennas of the base station, and has no antennas of its own. Because these antennas are directly connected to the LDA, they are considered part of the LDA. In a highly integrated implementation, the LDA is not only connected to the base station antennas, but is also connected to the internal electronic equipment of the base station. Such a connection can be used, for example, to communicate user channel assignment information from the base station to the LDA, and/or to communicate location information from the LDA to the base station. In a partial integration, as shown in FIG. 1B, an LDA 104 has its own antennas and is independent and separate from the base station, with the exception of a communication link for exchanging information. In a stand-alone implementation, shown in FIG. 1C, an LFA 108 and a base station 110 are not directly connected at all, although they may be indirectly connected via a larger network.

An integrated implementation of an LDA 112 with a base station 114 is illustrated in FIG. 2. The LDA 112 comprises a set of p antennas 116, a multichannel receiver 118 which coherently receives signals from the p antennas, a multi-purpose signal processor 120 which performs signal signature identification, database searching, and other required processing as will be described in detail below, and a memory storage device 122 accessible by the processor and used to store signal signature calibration data, location data, geographical map data, and/or other data as required. Location information determined by the processor is preferably sent over external communication lines 124 for use by other systems. The location information may also be provided to a routing controller 126 connected to a switching matrix 128 of the base station 114. The switching matrix 128 performs antenna beamforming or switching in dependence upon location-dependent signals from routing controller 126. A receiver 130 and transmitter 132 of the base station are connected to the antennas 116 by means of the switching matrix. Thus, the transmission and reception of the base station may be controlled by location-based routing information derived from LDA 112. The implementation shown in FIG. 2 is one example of a highly integrated implementation, corresponding to FIG. 1A. A stand-alone implementation of LDA 112 would not have routing controller 126, and would not share antennas 116 with base station 114. The essential principles of operation would otherwise be the same.

In contrast with the base station which communicates with a particular mobile using just one selected antenna at any given time, the LDA coherently receives signals from all the antennas simultaneously. The coherent multichannel receivers 118 preserve relative phase information between the signals received at the various antennas 116. As a result, subtle information about the spatial channel can be determined, as will be described in detail below. In particular, this spatial channel information includes multipath signal information, as shown in FIG. 3. Typically, in addition to a direct path signal 134 from a mobile device 136 to an LDA 138, there are one or more additional multipath signals 140 reflected from various environmental objects. In addition, there are typically various smaller local scatterers (not shown) positioned within a region 142 around the device. The coherently received signals at the LDA 138 thus include subtle spatial channel information corresponding to these reflected and scattered signals.

ARCHITECTURE FOR CDMA SYSTEMS

The wireless communication system can employ various conventional air standards and protocols, such as AMPS and CDMA. In the case of the more complicated CDMA standard, such as IS-95, some additional description will be helpful. In a CDMA communication system, all user devices share a common frequency band, and the different mobile devices are distinguished by their use of distinct PN spreading sequences. At the base station, the signals from a device are coupled to one of the antennas, downconverted to IF, and then digitized. The digitized signals are then correlated with PN sequences in order to separate the signals from different mobile devices. Low cross-correlation between the unique PN sequences ensures that there is little interference between mobiles within the base station service area. Well-known timing synchronization techniques are used to identify and lock onto the PN sequence for each mobile. After the user signal has been separated, it is typically sent into an inverse Hadamard transformer in order to extract Walsh symbols from the signal. Various decoding and interleaving functions may also be performed in order to reconstruct the information signal originating at the mobile device, as is well known in the art.

In an LDA 144 according to a CDMA embodiment of the present invention, the p antenna signals are coupled to coherent multichannel IF down-converters and A/D converters 146 to produce a set of p digitized complex signals, as shown in FIG. 4. Down-conversion and digitization are performed coherently so as to preserve the phase relationships between the separate signals from the p antennas. A common local oscillator and a master clock are used to maintain coherence between the parallel functions performed on all the signals from the p antennas. In the figure, the LDA 144 is integrated with a base station 148 which has its own

transmitter 150 and receiver 152. Stand-alone and partially integrated implementations, however, are also possible.

The p complex signals are separately despread in synchronized multichannel despreaders 154 of a CDMA receiver 156 of the LDA. In one embodiment, user PN sequence information is provided from the base station 148 so that the LDA can despread the signals. Alternatively, in stand-alone implementations, the LDA can obtain this information from the user device. For example, the user device can transmit its code channel information to an internet computer via a wireless modem link. The LDA can then query the computer and obtain the user information, thus by-passing the need to obtain it from the base station. In any case, once the PN sequence information for the user is obtained, the LDA despreads the p signals. In contrast with the base station receiver 152 which simultaneously performs despreading for all mobiles being served, the receiver 156 of the LDA sequentially time samples the signals from the set of current mobiles, thereby dramatically reducing hardware requirements and cost. To perform this sequential despreading, accurate code timing information is required. This information can be obtained from base station receiver 152. Alternatively, the code timing information can be acquired and tracked by the receiver of the LDA using well known techniques. Intermittent time samples are sufficient for the LDA because its purpose is not to acquire all the original signal information, but to acquire a spatial channel signature.

Although the LDA receiver architecture in a CDMA system is preferably adapted in the above manner, the high-level LDA architecture and principle of operation is the same.

Signal Measurement

Signal Vector Sample Acquisition

The LDA hardware coherently receives complex signal samples. These samples are later used to calculate spatial channel signatures, which are the basis for location determination. More specifically, the p antennas are used to receive complex signals $x_1(t)$, $x_2(t)$,..., $x_p(t)$, respectively, which are represented by a p-dimensional signal vector $\mathbf{x}(t) = [x_1(t), x_2(t),..., x_p(t)]^T$. At a moment t in time, each component $x_j(t)$ of this vector is a complex number having both amplitude and phase information from one of the antennas. In general, the dimension of the array vector $\mathbf{x}(t)$ is equal to p, the number of antennas in the array. The value of p is preferably in the range from 2 to 12, and is more preferably in the range from 4 to 8. Most preferably, the value of p is conveniently chosen to be 6 so that the existing antennas of a base station may be used.

SIGNAL ACQUISITION IN CDMA SYSTEMS

Signal acquisition in a CDMA system is more complicated, and therefore will be discussed in more detail. As is well known in the art, a conventional CDMA receiver can isolate multipath parts of a signal if their differential delay is more than one chip length. The signal parts are normally extracted by "fingers" of the receiver and then combined after temporal alignment to get improved signal strength. Each finger comprises a correlation receiver matched to the exact delay associated with a particular multipath part. Note, however, that this standard technique only distinguishes temporally distinct multipath parts, and does not distinguish spatially distinct multipath parts that have similar temporal delays.

The CDMA receiver 156 in the LDA 144 of FIG. 4 adapts the above technique for separating multipath parts in order to provide refined discrimination in location finding. For simplicity in the following discussion, we consider a signal from a single mobile device. At the p antennas of the LDA, this signal gives rise to a set of p coherently received signals $x_1(t)$, $x_2(t)$,..., $x_p(t)$. In the synchronized multichannel despreaders 154, each component $x_j(t)$ of this set is then decomposed using q correlation receivers into q temporally distinct signals $x_{j,1}(t)$,...,$x_{j,q}(t)$, where j is the antenna index of the signal and q is the number of fingers used. Thus, a total of $p \times q$ correlation receivers are used. Preferably, q is in the range from 1 to 8. More preferably q is in the range from 2 to 6. Most preferably, q=4. The multipath parts contained within a given finger all have delays within one chip from each other, while the delays between fingers are more than one chip. Each set of p samples from a given finger i is represented by a p-dimensional vector $\mathbf{x}^{(i)}(t)=[x_{1,i}(t),...,x_{p,i}(t)]^T$. All q vectors $\mathbf{x}^{(1)},...,\mathbf{x}^{(q)}$ are then sent to a signal processor 158 for subspace determination, as will be described further below.

The CDMA receiver 156 contains a searcher 160 that searches the original signals $x_1(t)$, $x_2(t)$,..., $x_p(t)$ for the best code delays to be used by the q despreaders. The searcher produces a code correlation output that represents the degree to which the delayed code matches the incoming signals. A sequence of L delay values $\tau_1,...,\tau_L$ are selected that are spaced by 1/2 chip length. Typically, L is approximately 200, so that the temporal span of the sequence is 100 chips. At each of the delay values, a corresponding code correlation value for the signal is measured from the code correlation output. The code correlation values from the jth antenna is represented as a sequence $C^{(j)}(\tau_1),...,C^{(j)}(\tau_L)$, where $C^{(j)}(\tau_i)$ is the value of the correlation between the signal $x_j(t)$ and a code with temporal delay τ_i. The

correlation output sequences for all p signals are sent to the signal processor 158 for construction of the correlation signature.

The searcher 160 examines the code correlation output to determine a set of q time delays $\tau^{(1)},...,\tau^{(q)}$ which correspond to the strongest correlations. There are various well known methods of determining such time delays. For example, these time delays may be determined by selecting the q values of τ that correspond to the q largest local maxima in the set $\{C^{(j)}(\tau_i) : j=1,...p; i=1,...,L\}$. Once these delays are determined, they are then sent to the despreaders 154 to control the despreading of each of the q fingers corresponding to these delays. The delays are also sent to the processor 158 for signature determination.

In order to achieve optimal use of hardware, the signals from the receivers can be sampled at regular time intervals. This optimization, however, requires some modification of conventional CDMA receiver architecture, which will now be described in detail with reference to FIGS. 5 and 6. In the following description, it is assumed that p=6 and that the IS-95 standard is used. The principles of this optimization, however, do not depend on these particular assumptions. Moreover, it should be emphasized that the present invention does not require this optimization in order to be usefully implemented.

It should be noted that the CDMA signal from each device has a standard temporal structure. In particular, the CDMA signal is composed of a sequence of temporal frames, each having a duration of 20 ms and containing 192 bits of information, as shown in FIG. 5. Each frame, in turn, is divided into 16 power control groups, each having a 1.25 ms duration. At high data rates, all 16 power control groups contain information. At the lowest data rate, only two power groups are active, i.e. contain information. At low rates, the placement of the active groups within the frame is pseudorandom.

As shown in FIG. 6, the signals from each user device in the coverage area of the LDA are coupled to the six antennas and received by a corresponding bank of six receivers 164. These receivers are coherently synchronized so that they preserve the relative phase information between the signals coupled to the six antennas. Each receiver downconverts the signal from one antenna to baseband, and then digitizes the signal to produce I and Q signal components. At this point, the signals from the various user devices have not yet been distinguished. The six digitized signals produced by the receiver bank 164 are sent to a corresponding bank of six signal buffers 166. Each signal buffer stores data samples covering several recently received digitized signal frames. Typically, each buffer is large enough to store three or more frames of data. At periodic intervals of 1.25 ms, a buffer

control circuit 168 calculates a buffer address that is used to select a power control group from the signal frames currently in each buffer. The specific buffer address is calculated so that during each power group time interval an active power group is selected from one of up to 16 distinct user phones. The output from each of the six buffers, therefore, is a data stream of selected power groups delayed by approximately three frames, where each of the 16 power group intervals in a frame can contain an active power group from one of up to 16 distinct user signals. Buffer control 168 sends a common set of signals to the buffers in signal buffer bank 166. These signals include buffer record and playback addresses, read/write signals, and buffer configuration data.

The six data streams from the buffer bank 166 are sent for despreading to a bank of six corresponding despreaders 170. In each despreader, the incoming data stream of selected power groups is correlated with appropriate PN sequences in order to despread the data. In a CDMA communication system, all users share a common frequency band, and the different mobile phones are distinguished by their use of distinct PN spreading sequences. Low cross-correlation between the unique PN sequences ensures that there is little interference between different users within the base station service area. In addition, low cross-correlation between distinct delayed versions of a given PN sequence ensures that there is little interference between various multipath parts of a signal originating from a single user. Well-known timing synchronization techniques are used to identify and lock onto the PN sequences of the multipath parts for each user.

In contrast with conventional use, despreaders in the present apparatus have their PN sequences changed every 1.25 ms by a despreader control circuit 172. The PN sequence is changed in synchronization with the transition between power groups so that, during each of the 16 power groups in a frame, the despreader uses the PN sequence corresponding to one of 16 users. The output from each despreader, therefore, is a despreaded I/Q data stream where each of the 16 power group intervals in a frame contains the despreaded signal from one of up to 16 user signals.

It is significant to note that the resulting six signal data streams do not contain all the information transmitted from the mobile phones. Rather, each frame coming out of the despreaders contains up to 16 active power group samples derived from up to 16 different mobile phones. Note that since the despreading essentially separates the multipath parts with differential delays greater than the chip period, it is possible to obtain the spatial signatures of all the significant multipath parts (referred to as fingers) of every mobile. In the present system, up to four fingers per mobile can be despread. The despreader output is used for determining spatial signal information, as will be described in more detail below.

We now turn to a description of the operation of buffer control circuit 168 and despreader control circuit 172. A common set of signals are sent from despreader control 172 to despreader bank 170. Specifically, these signals include two PN sequences: a combined I despreading sequence and a combined Q despreading sequence. Each of these sequences is a chip-by-chip product of all the spreading signals involved in spreading the signal in the transmitter. In the case of IS-95, these spreading signals include the long code, the Walsh codes, and the short I or Q sequences.

It is important to note that the Walsh codes are normally used as the transmitted symbols and thus contain the transmitted signal information. The present technique, however, treats the Walsh code as just another spreading signal. Including the Walsh code as part of the spreading signal provides improvements in processing at the LDA receiver in determining the phase of the received signals. In the preferred embodiment, the Walsh code information is obtained by sending the decoded data bits from the CSM board through a convolutional encoder, an interleaver, and a Walsh encoder, just as was done in the mobile prior to transmission. It will be appreciated that other codes or training sequences used by various other standards can be used just as the Walsh codes are used in the IS-95 standard described in this embodiment. It will also be appreciated that the Walsh codes could, in principle, be provided by the CSM board since the decoders determine the Walsh codes in order to produce the data stream. Although presently existing CSM integrated circuits do not provide Walsh code output, such integrated circuits may be produced in the future and could be used in the context of the present invention.

A despread IRQ (DES. IRQ) signal is issued on any power control group timing interval transition and serves to trigger the microprocessor 174 to load the next set of despreading parameters into the despread control and buffer control. The GPS IRQ is issued on each UTC second boundary and triggers the microprocessor to perform various housekeeping tasks. The system bus 176 carries information between system components. For example, data sent over the bus includes system reset commands, buffer address information for data playback, PN sequence states for despreading, PN mask information for data despreading, Walsh codes for data despreading, and CSM data and control information.

The six digitized signals produced by the receiver bank 164 are sent to a conventional CDMA modem board 178 which contains 16 conventional CSM integrated circuits which contain searchers, despreaders, fast Hadamard transform (FHT) processors, deinterleavers, decoders, and other well-known circuitry required to produce Walsh symbols and other signal information from the signals received from up to 16 mobile devices. The conventional CDMA modem board 178 does not produce spatial signal information. It does, however, provide data transmitted by each one of the user devices, the rates of transmission for each

user, PN sequence information, finger offset information for up to eight paths per user, frame offset information, and power group placement information. This information is made available over the data bus 176 to the microprocessor 174, which computes buffer addresses that are sent over the bus to the buffer control circuit 168, and PN sequences that are sent over the bus to the despreader control circuit 172. The purpose of the three-frame delay of the buffers is to allow time for the microprocessor to compute the buffer addresses, PN sequences, and other control parameters. A GPS timing circuit 180 is used to provide precise timing and synchronization information to CDMA modem board 178, buffer control circuit 168, and despreader control circuit 172. The signals sent from GPS timing circuit to receiver board 178, buffer control 168, and despread control 172 include a CHIPx16 clock (1.2288 x 16 MHz) and a pulse per 2 second signal (even second pulse).

The six output data streams from the despreaders 170 are low-pass filtered and then made available on a DSP data bus 182. These samples are then collected by a digital signal processor (DSP) 184. The DSP first performs a frequency estimation that is aimed at nulling the frequency error of the sampled signals. This frequency error is the result of the difference in frequencies between the user transmitter and the base station receiver. Since the frequency error can be up to several hundred Hertz, when the signal is despreaded and downconverted to baseband, it will have a residual non-zero frequency. Therefore, since signal samples in the present system are averaged over relatively long periods of time, the residual frequency must be corrected to prevent the samples from averaging out to zero. The DSP therefore first determines the residual frequency, and then corrects it before averaging the samples. This correction data is used by receiver control 186 to set receiver frequency and attenuation of receivers 164.

The specific functions performed by the microprocessor 174 include:

1. Initializing and controlling CSMs, GPS timing, buffer control, and despreader control.
2. Reading rates, offsets, active power groups, and transmitted data of subscribers from CSMs.
3. Computing transmitted Walsh codes from the received data.
4. Loading Walsh codes into despreader control before each power control group interval transition.
5. Loading playback address into buffer control before each power control group interval transition.
6. Receiving subscriber data from the DSP for despreading.
7. Sending, for each batch of data sent to the DSP from the despreader, a descriptor to the DSP identifying the subscriber associated with the data.

The specific functions performed by the DSP 184 include:

1. Computing a frequency error for each subscriber.
2. Correcting the frequency error for each received data batch.
3. Computing covariance matrices for each data batch.
4. Transferring covariance matrices to the location finding processor 188.
5. Transferring instructions to the microprocessor (e.g., subscriber lists and parameters)

The specific functions performed by the receiver control 186 include:

1. Setting the receiver frequency.
2. Setting the receiver attenuation.

In order to compute the spatial signature of a CDMA signal, one must first despread it. To determine the spatial signature, however, it is not necessary to capture or even compute the actual information data stream. For the purposes of the spatial signature measurement technique of the present invention, the important information is not the information data stream itself, but rather the spatial channel information derived in part from the relative phase information between the antennas of the array. Consequently, the present technique is distinct in motive, method, and result from known CDMA reception techniques. It provides an efficient method and system for simultaneously determining spatial signal information for multiple users in a CDMA communications system.

Data Collection and Averaging

Signal Batches and Standard Averaging

In a preferred embodiment, a p-dimensional received signal $\mathbf{x}(t)$ for a specific mobile device is regularly sampled during a sampling interval to produce a batch of signal vector samples, $\mathbf{x}(t_1), \mathbf{x}(t_2),\ldots, \mathbf{x}(t_N)$. In one embodiment illustrated in FIG. 7A, approximately 100 samples are taken during a 1 ms sampling interval, i.e., the signal is sampled every 10 μs, so that the difference $\Delta t_i=|t_i-t_{i+1}|$ is 10 μs. The outer products of these 100 vectors in the 1 ms batch are then combined to form a $p\times p$ covariance matrix for the batch.

For each mobile device, a batch of signal samples is collected once every 50 ms, as shown in FIG. 7B, and a corresponding batch covariance matrix is calculated. The batch covariance matrices for a given mobile device are then collected over the course of a few seconds (e.g., 5 s), as shown in FIG. 7C. These batch covariance matrices are then averaged to form a p×p signal covariance matrix, $\mathbf{R}$, which is normalized such that Tr $\mathbf{R}$ = 1. This normalized covariance matrix is used as the basis for subsequent calculations, as will be described below.

Because each batch spans only 1 ms, there is sufficient time using this technique to sample signals from up to 50 different user devices in a 50 ms interval. In other words, the signals from a first user device are sampled during a first 1 ms interval, the signals from a second user device are sampled during a second 1 ms interval, and so on. After 50 ms, the signals from the first user device are again sampled.

Those skilled in the art will appreciate that similar sampling method also may be implemented using various other values for the time intervals, number of signal vectors sampled per batch, etc. In addition, one can also use a non-uniform sampling scheme wherein each mobile is sampled at a period inversely proportional to the speed of its physical movement, or according to other criteria. Although the present description is focused upon the processing of the signals from a single user device, in the preferred embodiment, the techniques described herein are applied to signals from a number of users.

It will be recognized by those skilled in the art that although this sampling procedure is appropriate for the AMPS cellular standard it can be adapted to various other modulation schemes as well. In the case of a CDMA cellular network, for example, spread spectrum signals from the antenna array are digitized and passed through synchronized multichannel despreaders to produce the p-dimensional array vectors $\mathbf{x}(t)$ corresponding to each mobile. These vectors can then be sampled and averaged to form a covariance matrix in the manner outlined above. More specific details of such a CDMA implementation will now be described.

In the preferred embodiment, a batch of signals for a given mobile is collected every 60 ms in a time interval of length 1.25 ms. Thus, up to 48 different mobiles can be sampled in the 60 ms interval. Obviously, more mobiles can be handled by either decreasing the 1.25 ms batch interval length, or increasing the 60 ms repetition interval. In addition, the hardware can be duplicated so that several mobiles are processed in parallel rather than sequentially. These various implementations involve consideration of various trade-offs, but do not alter the essential technique of the present invention.

The outer products of the signals in each batch are combined to form a batch covariance matrix. If signals from multiple fingers are available, there will be a batch covariance matrix for each finger. The batch covariance matrices for each finger are then averaged over several seconds to produce a signal covariance matrix $\mathbf{R}$. If there are multiple fingers, there will be multiple signal covariance matrices.

The sampled time delays and correlation data are also averaged in an analogous manner over the several second period. These averaging techniques help to reduce the effects of noise in the measured signature.

VELOCITY DEPENDENT AVERAGING

In addition to uniform averaging, various types of nonuniform averaging can be used to increase the efficiency and performance of the signal acquisition. In particular, estimates of the mobile device velocity can be used to control the averaging, as will now be described in relation to FIG. 7D. For a given mobile device, the batch covariance matrices for approximately 100 batches are averaged over a few seconds as described earlier to form a p×p signal covariance matrix $\mathbf{R}$. According to the present velocity-dependent averaging technique, this initial covariance matrix is denoted $\mathbf{R}_{t_0}$, where t_0 is the time $\mathbf{R}$ is measured. As the system continues to operate in real time, another signal covariance matrix $\mathbf{R}_{t_1}$ is determined in the same way from the batch covariance matrices measured over the course of a few seconds that elapse between time t_0 and a later time t_1. In this manner, a sequence of signal covariance matrices $\mathbf{R}_{t_0}, \mathbf{R}_{t_1}, \mathbf{R}_{t_2},..., \mathbf{R}_{t_n}$ is generated, where $\mathbf{R}_{t_n}$ denotes the most recent covariance matrix. Preferably, the difference $\Delta t_i = |t_i - t_{i+1}|$ is in the range from 0.1 to 20 seconds, but is more preferably between 1 and 10 seconds, and most preferably 5 seconds (assuming uniform sampling).

In accordance with the teaching of the present invention, an average signal covariance $\overline{\mathbf{R}}_{t_n}$ is produced in real time by forming a linear combination of the covariance matrices $\mathbf{R}_{t_0}, \mathbf{R}_{t_1}, \mathbf{R}_{t_2},..., \mathbf{R}_{t_n}$. In the preferred embodiment, the specific manner in which the covariance matrices are combined to produce the average covariance matrix depends on estimates of the transmitter velocity, represented by $v_{t_0},...,v_{t_n}$. Preferably, the covariance matrices combined to form the average covariance matrix are those collected over a time interval in which the transmitter has moved a distance D, where D is a predetermined distance corresponding to the average spatial span between the calibrated signature locations. Generally, if the velocity estimate is large, then the matrices are combined such that the most

recent covariance matrices contribute significantly to the average covariance, while the less recent covariance matrices contribute relatively little to the average covariance matrix. Conversely, if the velocity estimate is small, then the contribution of the less recent covariance matrices is not so small. The velocity estimates can be determined using various techniques known in the art. Alternatively, velocity can be estimated based on recent location estimates derived from techniques of the present invention, or directly from recent covariance matrices, as will be described below. For the purposes of this description, we assume velocity estimates are positive velocity magnitudes.

In one implementation of the preferred embodiment, an average covariance matrix $\overline{\mathbf{R}}_{t_n}$ is calculated by evaluating

$$\overline{\mathbf{R}}_{t_n} = (1/D_m) \sum_{i=m}^{n} v_{t_i} \Delta t_i \mathbf{R}_{t_i} = (v_{t_m} \Delta t_m \mathbf{R}_{t_m} + \ldots + v_{t_n} \Delta t_n \mathbf{R}_{t_n})/D_m,$$

where $D_m = v_{t_m} \Delta t_m + \ldots + v_{t_n} \Delta t_n$ and m is selected such that $D_m \approx D$. In other words, m is selected so that the past covariance matrices $\mathbf{R}_{t_m}, \ldots, \mathbf{R}_{t_n}$ are those collected over a time interval in which the transmitter has moved a distance D. It will be noted that, assuming the time intervals $\Delta t_m, \ldots, \Delta t_n$ are constant, the coefficients that determine the relative weights of the past covariance matrices are proportional to the estimated transmitter velocities. A covariance matrix corresponding to a small velocity will therefore contribute less to the average covariance matrix than a covariance matrix corresponding to a large velocity. In accordance with this general principle, those skilled in the art will be able to construct many other formulas for calculating the average covariance matrix from past covariance matrices.

In another implementation of the preferred embodiment, the average covariance matrix is calculated from the most recent past covariance matrix and velocity estimate and the last average covariance matrix. In other words, $\overline{\mathbf{R}}_{t_n}$ is calculated recursively by evaluating

$$\overline{\mathbf{R}}_{t_n} = f(v_{t_n}, \mathbf{R}_{t_n}, \overline{\mathbf{R}}_{t_{n-1}}),$$

where f is a function of the current estimated velocity of the transmitter v_{t_n}, the current covariance matrix $\mathbf{R}_{t_n}$, and the most recent prior average covariance matrix $\overline{\mathbf{R}}_{t_{n-1}}$. This is a recursive definition since the covariance matrix $\overline{\mathbf{R}}_{t_{n-1}}$ is similarly calculated from

$$\overline{\mathbf{R}}_{t_{n-1}} = f(v_{t_{n-1}}, \mathbf{R}_{t_{n-1}}, \overline{\mathbf{R}}_{t_{n-2}}).$$

Thus, one may write

$$\overline{\mathbf{R}}_{t_n} = f(v_{t_n}, \mathbf{R}_{t_n}, f(v_{t_{n-1}}, \mathbf{R}_{t_{n-1}}, \ldots f(v_{t_1}, \mathbf{R}_{t_1}, f(v_{t_0}, \mathbf{R}_{t_0}, \mathbf{R}_{t_0}))\ldots)),$$

where $v_{t_0},\ldots,v_{t_n}$ are the estimated velocities at times $t_0,\ldots,t_n$. Although many possible functions f may be selected for use, in one implementation the function f is defined by forming the following linear combination of $\overline{\mathbf{R}}_{t_{n-1}}$ and $\mathbf{R}_{t_n}$:

$$\overline{\mathbf{R}}_{t_n} = f(v_{t_n}, \mathbf{R}_{t_n}, \overline{\mathbf{R}}_{t_{n-1}}) = \lambda_{t_n} \overline{\mathbf{R}}_{t_{n-1}} + (1-\lambda_{t_n}) \mathbf{R}_{t_n},$$

where λ_{t_n} is a velocity-dependent coefficient that takes values between 0 and 1. Values of λ_{t_n} near 1 result in large retention of past covariance information, while values of λ_{t_n} near 0 result in large forgetting of past covariance information.

In one implementation of the present invention, the values for $\lambda_{t_0},\ldots,\lambda_{t_n}$ are calculated from time-dependent velocity estimates $v_{t_0},\ldots,v_{t_n}$. The value of λ_{t_n} is calculated such that a very large velocity estimate v_{t_n} results in a value of λ_{t_n} near 0, and hence large forgetting of past covariance information, while small velocity estimates result in values of λ_{t_n} near or equal to 1, and hence large or total retention of past covariance information. Although many formulas have these properties, one example of a formula for calculating λ_{t_n} is the following:

$$\lambda_{t_n} = e^{-v_{t_n}\Delta t_n / D},$$

where Δt_n is on the order of a few seconds, D is on the order of a few tens of meters, and v_{t_n} is the current estimate of the transmitter velocity. For example, in the case where $\Delta t_n = 1$ s and D=25 m, a velocity of $v_{t_n} = 0$ will result in $\lambda_{t_n} = 1$. A velocity of

v_{t_n} = 25 m/s = 90 km/hr), on the other hand, will result in $\lambda_{t_n} = e^{-1} = 0.368$. It will be appreciated that many other equations for λ_{t_n} may be used to produce substantially equivalent effects. For example,

$$\lambda_{t_n} = 1/(1 + v_{t_n})$$

or

$$\lambda_{t_n} = 1/(1 + (v_{t_n})^2).$$

In an alternate embodiment, the value for λ_{t_n} is selected from a finite set of predetermined values $\lambda_1,\ldots,\lambda_m$. The particular value selected depends on the value of v_{t_n}. For example,

$$\lambda_{t_n} = \begin{cases} 1 \text{ if } v_{t_n} < v_{low} \\ 0 \text{ if } v_{t_n} > v_{high} \\ .5 \text{ otherwise,} \end{cases}$$

where v_{low} and v_{high} are predetermined low-velocity and high-velocity thresholds, respectively.

This technique for calculating an average covariance matrix from past covariance matrices has important advantages. Because the current covariance matrix of a very slowly moving or stationary transmitter has less information than that of a moving transmitter, it correlates weakly with location and introduces ambiguity into the location finding process. The present technique, however, retains past covariance information when the velocity is small or zero, and overcomes this problem. When the transmitter is moving quickly, on the other hand, the current covariance matrix correlates strongly with the current location, while the past covariance matrices correlate strongly with past locations. Because the present technique forgets past covariance information in this case, it provides an automatic and adaptive way to generate an average covariance matrix that is most highly correlated with the current location.

Signature Computation

The signal signature for a mobile device captures the essential spatial channel information derived from the signals received at the antenna array. Because the signal signature depends on the spatial channel information, it is highly correlated with the spatial location of the mobile. The signal signature preferably includes location-dependent aspects of the spatial channel, and preferably excludes as much as possible location-independent aspects such as noise. More preferably, the signal signature includes signal multipath information resulting from multipath propagation effects in the environment, preferably derived from phase and amplitude information measured at an antenna array. Most preferably, the signal signature includes one or more of the following elements: a spatial subspace of the signal covariance matrix, relative time delays of signal multipath parts, and code correlation information. The signature can also be represented in other ways, such as higher order spectra of the signals. Signal subspaces may be also extracted via other techniques involving cumulants and higher order statistics in conjuction with second order statistics represented by the signal covariance matrix. Cumulants can then be used to recover more phase information than is possible from the covariance matrix alone and in addition possess more robust properties in the presence of additive Gaussian observation noise.

Covariance Matrix Subspace Calculation

In a preferred embodiment, the signal signature includes as its primary component a signal subspace $\mathbf{U}$ spanned by the dominant eigenvectors of the signal covariance matrix $\mathbf{R}$. The dominant eigenvectors are defined as the eigenvectors of $\mathbf{R}$ corresponding to the largest eigenvalues that collectively capture at least certain percentage of the total signal energy. Preferably, this percentage is at least 70%, but is more preferably 90%. It should be emphasized that the signal subspace may be determined by various different criteria as well.

In the case of a CDMA system, q signal subspaces $\mathbf{U}^{(1)},\ldots, \mathbf{U}^{(q)}$ are preferably calculated for the q signal covariance matrices $\mathbf{R}^{(1)},\ldots, \mathbf{R}^{(q)}$ of the q fingers. It should be noted that each multipath signal in a finger i normally contributes an extra dimension to the subspace $\mathbf{U}^{(i)}$. Consequently, the subspace will have an increased dependence upon location in the presence of severe multipath.

Correlation and Time Delay Information

In addition to the signal subspace, differential time delays for the multipath parts can also be used as part of the signal signature. These delays can be used to further enhance the signal

signature in order to provide additional location dependence. As a result, the delays provide the system with increased location accuracy, and also can be used to resolve ambiguities in location, such as may arise in the case of a stationary phone using a narrowband modulation scheme. (Note that, in contrast with the time difference data in the prior art which consists of time differences of the direct signals arriving at several different base stations, the differential time delay data used herein involves the time differences between the multipath signal parts arriving at a single base station.)

In one embodiment, differential time delays between multipath signals may be calculated as follows. First one performs a blind estimation of the array response matrix **A** during the calibration procedure by techniques well-known in the art, such as high-order statistics. The columns of the matrix **A** consist of the set of linearly independent array response vectors. Note that in the case where the differential delays are small compared with the reciprocal of the signal bandwidth, the invention exploits transmitter movement to decorrelate signals and determine **A**. The matrix **A** is then used to determine a weight matrix **W** such that $\mathbf{WA}=\mathbf{I}$. Using **W** and the sampled signals, one then resolves the q multipath signal parts and calculates their relative time delays, $\tau^{(1)},\ldots,\tau^{(q)}$. These time delays and the matrix **A** associated with each location are stored in the calibration database. (Since the signal subspace may be determined from **A**, it is not necessary to store the signal subspace if **A** is stored.) When attempting to locate a transmitter with an unknown location, this additional information in the database may be used to improve the accuracy as follows. After determining a set of likely locations using subspace matching, the stored matrix **A** is used to calculate differential time delays based on the sampled signals, as was done in the calibration procedure. These time delays are then compared with the stored time delays to help resolve location ambiguities.

In the case of a CDMA implementation, the blind estimation technique is not required to obtain the time delays $\tau^{(1)},\ldots,\tau^{(q)}$ since this delay information is provided by the signal acquisition, as was described above. Preferably, the time delay signature is represented as a vector defined by $\tau=[\tau^{(1)},\ldots,\tau^{(q)}]^T$. In addition, a CDMA implementation also provides the code correlation data represented as a matrix $\mathbf{C}=[\mathbf{C}^{(1)T},\ldots,\mathbf{C}^{(p)T}]^T$, where $\mathbf{C}^{(j)}=[C^{(j)}(\tau_1),\ldots,C^{(j)}(\tau_L)]^T$. The subspaces $\mathbf{U}^{(1)},\ldots,\mathbf{U}^{(q)}$, together with the matrix **C** and the vector τ, are used to construct a signal signature that captures essential location-dependent information about the spatial channel for the mobile at its current location. In addition, the covariance matrices $\mathbf{R}^{(1)},\ldots,\mathbf{R}^{(q)}$ can also be used as part of the signature.

The signal signature in the database for each location d_k preferably includes the calibrated spatial signature $S_k=\{U_k^{(1)},...,U_k^{(q)};\ R_k^{(1)},...,R_k^{(q)}\}$, the calibrated temporal delay signature $\tau_k=[\tau_k^{(1)},...,\tau_k^{(q)}]^T$, and the calibrated correlation signature $C_k=[C_k^{(1)T},...,C_k^{(p)T}]^T$. It should be emphasized that the signal signature is not limited to the specific examples given here, but may include other characterizations as well. In addition, it should be emphasized that the signal signature need not contain all the above components. For example, it might contain just a single subspace, U_k.

Velocity Estimation

In accordance with the present invention, the real-time velocity of the phone can be determined by the following method. Because the 1 ms batch sampling time is short compared to the movement of the phone, the batch covariance matrix will have, to a close approximation, rank 1. Thus, denoting the batch covariance matrix by $\mathbf{R}$, we may write

$$\mathbf{R} \approx \mathbf{x}\,\mathbf{x}^H, \tag{1}$$

where $\mathbf{x}\,\mathbf{x}^H$ represents the rank-1 approximation to $\mathbf{R}$, i.e. the vector $\mathbf{x}$ is the dominant eigenvector of $\mathbf{R}$ and $\mathbf{x}^H$ is its Hermetian conjugate.

Now consider a second covariance matrix $\mathbf{R}'$ measured a short time δt after $\mathbf{R}$ is measured (e.g., δt=50 ms), again over the course of a 1 ms time interval. Then write

$$\mathbf{R}' \approx \mathbf{x}'\,(\mathbf{x}')^H, \tag{2}$$

where $\mathbf{x}'\,(\mathbf{x}')^H$ represents the rank-1 approximation to $\mathbf{R}'$.

In a typical multipath environment, the physical displacement of the transmitter is, to a first order approximation, proportional to the angular displacement between the vectors $\mathbf{x}$ and $\mathbf{x}'$ in signal space. The greater the displacement of the phone during the interval δt, the greater the angle between $\mathbf{x}$ and $\mathbf{x}'$. Thus, in order to estimate the velocity of the phone, it would be desirable to measure the angular velocity of the signal vector by comparing two consecutive

measurements of $\mathbf{x}$ separated by a known time interval δt. The computation of $\mathbf{x}$, however, would involve a computationally expensive calculation of the eigenvalues and eigenvectors of $\mathbf{R}$. Accordingly, the present inventors have developed the following technique for determining velocity without the need for such complex computations.

Define

$$\delta\mathbf{R} = \mathbf{R}' - \mathbf{R} \tag{3}$$

and

$$\delta\mathbf{x} = \mathbf{x}' - \mathbf{x}. \tag{4}$$

Using these definitions, we may rewrite eq. 2 as

$$\mathbf{R} + \delta\mathbf{R} = (\mathbf{x} + \delta\mathbf{x})(\mathbf{x} + \delta\mathbf{x})^H. \tag{5}$$

Expanding the right-hand side of eq. 5, we obtain

$$\mathbf{R} + \delta\mathbf{R} = \mathbf{x}\,\mathbf{x}^H + \delta\mathbf{x}\,\mathbf{x}^H + \mathbf{x}\,\delta\mathbf{x}^H + \delta\mathbf{x}\,\delta\mathbf{x}^H. \tag{6}$$

Subtracting eq. 1 from this, we then get

$$\delta\mathbf{R} = \delta\mathbf{x}\,\mathbf{x}^H + \mathbf{x}\,\delta\mathbf{x}^H + \delta\mathbf{x}\,\delta\mathbf{x}^H. \tag{7}$$

Now, using eq. 7, one can calculate $\|\delta\mathbf{R}\|^2 = \mathrm{Tr}(\delta\mathbf{R}\,\delta\mathbf{R}^H)$ and $|\mathrm{Tr}(\delta\mathbf{R})|^2$, and then subtract the resulting expressions to yield

$$\|\delta\mathbf{R}\|^2 - |\mathrm{Tr}(\delta\mathbf{R})|^2 = 2|\mathbf{x}|^2|\delta\mathbf{x}|^2 - 2|\mathbf{x}^H\,\delta\mathbf{x}|^2. \tag{8}$$

Define

$$\delta\mathbf{x}_T = \delta\mathbf{x} - (\delta\mathbf{x}^H\,\mathbf{x}_U)\,\mathbf{x}_U, \tag{9}$$

where $\mathbf{x}_U = \mathbf{x}/|\mathbf{x}|$ is the unit vector in the direction of $\mathbf{x}$. Thus, $\delta\mathbf{x}_T$ is $\delta\mathbf{x}$ minus the portion of $\delta\mathbf{x}$ in the direction of $\mathbf{x}$. We can therefore think of $\delta\mathbf{x}_T$ as the tangential component of $\delta\mathbf{x}$.

Using eq. (9) we can rewrite eq. (8) as

$$\| \delta \mathbf{R} \|^2 - |\mathrm{Tr}(\delta \mathbf{R})|^2 = 2|\mathbf{x}|^2|\delta \mathbf{x}_T|^2. \quad (10)$$

Let $\delta\theta$ be the angle between $\mathbf{x}'$ and $\mathbf{x}$. Then, assuming $\delta \mathbf{x}_T << \mathbf{x}$, we have $|\delta \mathbf{x}_T|/|\mathbf{x}| = \tan(\delta\theta) \approx \delta\theta$, and hence $|\delta \mathbf{x}_T| \approx |\mathbf{x}|\,\delta\theta$. Substituting this in eq. 10, we get

$$\| \delta \mathbf{R} \|^2 - |\mathrm{Tr}(\delta \mathbf{R})|^2 \approx 2|\mathbf{x}|^4(\delta\theta)^2. \quad (11)$$

Finally, because $\mathbf{R} = \mathbf{x}\,\mathbf{x}^H$, we have $\mathrm{Tr}(\mathbf{R}) = \mathrm{Tr}(\mathbf{x}\,\mathbf{x}^H) = |\mathbf{x}|^2$, and hence $|\mathbf{x}|^4 = [\mathrm{Tr}(\mathbf{R})]^2$. Substituting this in eq. 11 gives

$$\| \delta \mathbf{R} \|^2 - |\mathrm{Tr}(\delta \mathbf{R})|^2 \approx 2[\mathrm{Tr}(\mathbf{R})]^2\,(\delta\theta)^2. \quad (12)$$

Solving this for $\delta\theta$ we obtain

$$\delta\theta \approx \sqrt{\{\ \| \delta \mathbf{R} \|^2 - |\mathrm{Tr}(\delta \mathbf{R})|^2\ \} \ / \ 2[\mathrm{Tr}(\mathbf{R})]^2} \quad (13)$$

Notice that the right-hand side of this equation can be calculated with simple algebraic operations involving only $\delta\mathbf{R}$ and $\mathbf{R}$. This equation, therefore, is a function that gives a simple and computationally efficient way to compute the angular change in the signal vector directly from the measured batch covariance matrices.

The physical displacement of the phone, to first order approximation, is proportional to the angular displacement of the signal vector. To estimate the magnitude of the velocity of the phone at a time t, therefore, the following expression is computed:

$$|\mathbf{v}_t| = \alpha\ \delta\theta/\delta t\ , \quad (14)$$

where δt is the time difference between the measurements of $\mathbf{R}'$ and $\mathbf{R}$, and α is a constant of proportionality that is determined empirically. Notice that $|\mathbf{v}_t|$ is an estimate of the velocity over the period δt which is typically 5 to 50 ms. To obtain the average velocity over a longer period, say one second, one can use any of the averaging and smoothing techniques described above to a collection of velocity estimates collected within the longer period. It will be appreciated that other equations similar to eqs. 13 and 14 may be used to make similar

estimates of the phone velocity. Such substantially similar equations include, for example, mathematically equivalent expressions as well as equations involving a similar combination of the quantities $Tr(\mathbf{R})$, $Tr(\delta\mathbf{R})$, and $Tr(\delta\mathbf{R}\,\delta\mathbf{R}^H)$, or multiples of these quantities. The essential feature of the equation is that it is a simple, closed-form expression in terms of just $\mathbf{R}$ and $\mathbf{R}'$. It will also be appreciated that the direction of the velocity can be estimated by comparing successive locations that have been determined using a location-finding technique. Combining this direction estimate with the magnitude estimate, one may estimate the actual velocity vector, $\mathbf{v}$.

The value of $|v|$ may be used in various ways to improve the performance of a location finding system, as well as for other applications where a knowledge of transmitter movement may be of use.

Calibration Data Collection Procedure

The real-time location determination technique of the present invention makes use of a stored database of calibrated signal signature information and associated locations. The initialization of the system, therefore, preferably involves a calibration procedure in which signal signature and location information is collected. One procedure for collecting this data is as follows.

According to a preferred calibration procedure, a calibration vehicle follows an arbitrary trajectory in the vicinity of a LDA. The vehicle contains an active cellular telephone, a GPS receiver, and a computer for storing the real-time GPS position data of the vehicle along its trajectory. In a typical calibration procedure, the GPS location data along the trajectory are periodically stored on the computer together with the GPS clock time-stamp, typically at intervals on the order of 10 to 100 ms. Meanwhile, the transmitted signal from the cellular phone is received at the LDA, which is also equipped with a GPS receiver, and the signal signature is calculated and stored with the GPS clock time stamp. When the data from the vehicle and the LDA are combined and processed, differential GPS correction data obtained from the LDA are standard techniques are used to determine with high accuracy the vehicle location corresponding to each signature measured at the LDA. The signal signature and location information are then stored as raw calibration data at the base station.

Note that the calibration procedure may include the simultaneous use of several base stations and/or several vehicles moving within the service area. In addition, each vehicle may include several phones operating on different channels. For example, in an implementation for the AMPS standard, a set of 6 phones in a vehicle may be used to transmit at frequency intervals

of 2 MHz in order to provide the signature data with frequency coverage across a 10 MHz bandwidth. In this case, the raw calibration data contains 6 signatures corresponding to the 6 frequencies for each location along the vehicle trajectory. It will also be appreciated that the location data may be derived from techniques other than, or in addition to, GPS techniques. For example, the GPS location information can be supplemented by dead reckoning or other navigational information. Such supplementary location information is especially useful in cases where GPS reception is poor. The supplementary location information can be stored with the GPS information and post-processed in an off-line procedure as described above. Alternatively, the location information can be transmitted in real time to the base station during the calibration procedure.

The result of the calibration procedure for a single vehicle with a single phone is a sequential set of raw calibration data for a single trajectory, including a set of covariance matrices $\mathfrak{R}=\{\mathbf{R}_1,...,\mathbf{R}_N\}$ and a set of N corresponding locations $\mathfrak{D}=\{\mathbf{d}_1,...,\mathbf{d}_N\}$. The raw calibration data for a single trajectory is conveniently represented as a single set of ordered pairs, $\mathfrak{T}=\{(\mathbf{R}_1,\mathbf{d}_1),...,(\mathbf{R}_N,\mathbf{d}_N)\}$ indexed by the integers 1 to N. Because locations $\mathbf{d}_i$ and indices i are in one-to-one correspondence, locations may be identified by their corresponding location index, and vice versa. If time delay and/or code correlation information is also measured, this data is also recorded as part of the raw calibration data, so that data for a single trajectory is represented as ordered triplets or ordered quadruplets.

Typically, the calibration procedure will use one or more vehicles following M routes at the same or different times. The raw data collected from M routes is initially stored in a set of M files, which are also represented by $\mathfrak{T}_1,...,\mathfrak{T}_M$. In the case where only covariance matrix information is measured, each file $\mathfrak{T}_m$ contains a temporally sequential list of ordered pairs $(\mathbf{R}_1,\mathbf{d}_1),...,(\mathbf{R}_{N(m)},\mathbf{d}_{N(m)})$, where N(m) is the number of data points in route m. If additional information is measured, each file contains a list of ordered triplets, quadruplets, etc. Each data point, therefore, may be assigned a unique index pair (m,n), where m=1,...,M specifies the route and n=1,...,N(m) specifies the data point within the route, as shown in TABLE 1.

TABLE 1

Route 1	Route 2	...	Route m	...	Route M
(1,1)	(2,1)		(m,1)		(M,1)
(1,2)	(2,2)		(m,2)		(M,2)
. :	. :		. :		. :
(1,n)	(2,n)	...	(m,n)	...	(M,n)
. :	. :		. :		. :
(1,N(1))	(2,N(2))		(m,N(m))		(M,N(M))

Note that each route m will usually have a different number of data points N(m). The columns of Table 1, therefore, do not necessarily have the same number of rows.

The raw calibration data is used to form the calibration database which contains K calibrated signal signatures and K associated locations, as shown in TABLE 2. Each of the locations $\mathbf{d}_1,...,\mathbf{d}_K$ may be two or three dimensional, and may be assigned a date upon which it was last calibrated. The signal signature in the database for each location $\mathbf{d}_k$ includes the calibrated spatial subspace information, $\mathbf{S}_k$, and possibly also calibrated temporal delay information, τ_k, and code correlation information, $\mathbf{C}_k$. In a preferred embodiment, the covariance signature is $\mathbf{S}_k=\{\mathbf{U}_k;\ \mathbf{R}_k\}$ or, if multipath parts are resolved, $\mathbf{S}_k=\{\mathbf{U}_k^{(1)},...,\mathbf{U}_k^{(q)};\ \mathbf{R}_k^{(1)},...,\mathbf{R}_k^{(q)}\}$. The temporal delay signature preferably is $\tau_k=[\tau_k^{(1)},...,\tau_k^{(q)}]^T$, and the code correlation signature is $\mathbf{C}_k=[\mathbf{C}_k^{(1)T},...,\mathbf{C}_k^{(p)T}]^T$. It should be emphasized that the signal signature is not limited to the specific examples given here, but may include other characterizations as well.

TABLE 2

Location (x, y, z)	Signal Signature		
	Spatial Signature	Temporal Signature	Correlation Signature
$\mathbf{d}_1$	$\mathbf{S}_1$	τ_1	C_1
.	.	.	.
.	.	.	.
.	.	.	.
$\mathbf{d}_K$	$\mathbf{S}_K$	τ_K	C_K

Although the signal signature is a relatively stable function of location, certain changes in the signature may take place which may affect the accuracy of the database of calibrated signal signatures. Such changes may result from the construction or destruction of buildings, or from seasonal changes in the natural environment that affect multipath. Accordingly, the preferred embodiment of the present invention includes techniques for updating the database. A direct method involves performing the calibration procedure at regular intervals or continuously. A cost-effective method of continuous calibration could use a fleet of commercial delivery vehicles. Since such vehicles typically pass through many locations in a localized region, a dedicated calibration system could piggy-back on these vehicles and allow continuous updating of the database. Alternatively, or in addition, specialized vehicles could be sent out periodically to calibrate the service region. It should also be noted that in the case where two or more base stations can simultaneously receive signals from such a calibration unit, its signals can be used by all these base stations to independently calibrate their respective databases.

It is also possible to perform certain database corrections using only signals from regular phones, i.e., without using special calibration vehicles. For example, in the case where seasonal atmospheric changes cause alterations in the multipath, an analysis of signals over the course of several days or weeks can detect a gradual drift in the collective signal signatures. After clearly identifying such a drift, the database signatures can be corrected to compensate for the drift, thus eliminating the need for performing a calibration procedure. A similar technique can be used to correct the database to compensate for signal signature changes caused by the construction or destruction of reflecting objects in the environment. In this case, an analysis of signal signatures over time will display a consistent and gradual shift for those signatures associated with locations in the vicinity of the objects. Having

identified such bias, the database can then be compensated accordingly. As an aid to the identification of these environmental biases, base stations may share with each other certain information, e.g. the array response matrix A for a certain location. If both base stations detect a shift, it is likely due to an environmental change. It is a significant feature that high bandwidth communication channels are not required to communicate such information between base stations. In addition, geographical and environmental information can be used to detect these shifts. For example, because major highways do not typically change their location, vehicles being tracked regularly along such a highway will have known trajectories. This trajectory information can be used to identify and correct drifts in the calibration data.

It should be noted that, if a transmitter is stationary and if the differential time delays are much smaller than the reciprocal of the signal bandwidth, then the multipath and direct path signals will be coherent, i.e. they will differ only by a complex scalar factor. In this case, the measured signal subspace will be one-dimensional since the multipath signal does not contribute an additional dimension to the signal subspace. A moving transmitter, on the other hand, will decorrelate the direct and multipath signals over a distance of several wavelengths. For example, two multipath signals from a moving transmitter result in sufficient variation of subsequent signal vectors $\mathbf{x}(t_1),\ldots, \mathbf{x}(t_M)$ to permit the full subspace to be determined. Because it is preferable in the calibration procedure to have signal signatures comprising multi-dimensional subspaces, the calibration procedure of the present invention uses moving vehicles to advantageously decorrelate the direct and multipath signals, thereby permitting determination of the complete signal subspace. Although a stationary transmitter will have only a one-dimensional subspace, because this subspace is within the calibrated signal subspace it is still possible to locate the transmitter, albeit with less certainty than with a moving transmitter. In the case of wideband modulation schemes or frequency hopping, however, the full signal subspace may be determined even for a stationary transmitter.

Calibration Data Processing

In the preferred embodiment, the calibration process includes post-processing to optimize the calibration table. This optimization can involve eliminating redundant information, compressing the data for more efficient storage, and organizing the data for more efficient searching. The raw data contains redundancy due primarily to arbitrary and uncontrolled vehicle speeds and trajectories during the calibration data collection. A stopped or very slow moving vehicle, for example, can result in many redundant data points corresponding to nearly the same location (assuming uniform sampling of data points). Overlapping route trajectories also result in redundant data points. It is therefore advantageous to remove these

redundancies in order to generate an optimal calibration table from this raw data. The post-processing method comprises two main parts: data association and grid generation.

DATA ASSOCIATION

The data association procedure is preferably separated into two steps. The first step generates a route neighbor file for each route, while the second step generates a total route neighbor file for all routes.

The first step is performed as follows. For each data point (m,n) in a route m, a list $\mathfrak{N}_m$ of neighboring data points in the same route m is determined. A neighboring data point is defined to be any data point whose location is less than a predetermined distance D from the location of (m,n). In the preferred embodiment, the predetermined distance D is 5 to 10 meters, as this is the approximate accuracy of present GPS receivers and is comparable to a lane width on a typical road. It will be appreciated that other distances D may also be used. In this manner, a route neighborhood file $\mathfrak{N}_m$ for route m is constructed which contains a route neighbor list for each point in the route. TABLE 3 shows an example of a route neighborhood file $\mathfrak{N}_m$ containing route neighbor lists in route m for all points in route m.

TABLE 3: Route Neighbor File

Data Point	Route Neighbor List
(m,1)	(m,2);(m,3)
(m,2)	(m,1);(m,3);(m,4)
⋮	
(m,n)	(m,n-2);(m,n-1);(m,n+1);(m,n+2);(m,n+3)
⋮	
(m,N(m))	(m,N(m)-2);(m,N(m)-1)

Similarly, a route neighborhood file is produced for each of the M routes, resulting in a total of M route neighborhood files $\mathfrak{N}_1,\ldots,\mathfrak{N}_M$. corresponding to each of the routes $\mathfrak{T}_1,\ldots,\mathfrak{T}_M$.

After the M route neighborhood files are constructed, the second step of the data association procedure is performed. In this step, a total neighborhood file $\mathfrak{M}$ is constructed, combining information from all the routes. The total neighborhood file $\mathfrak{M}$ contains, for each data point in each route, a total neighbor list. The total neighborhood list for a point contains all the neighbors of the point selected from all data points in all routes. In other words, the total neighbor list for a point contains not only neighbors in the same route, but also neighbors taken from all the other routes. TABLE 4 shows an example of a total neighborhood file.

TABLE 4: Total Neighbor File

Data Point	Total Neighbor List
(1,1)	(1,2);(1,3);(2,12);(2,13);...;(M,54);(M,55)
. :	. :
(1,N(1))	(1,N(1)-1);(2,11);(2,12);...;(M,128)
. . .	. . .
(m,1)	(1,32);(2,78);...;(m,2);(m,3);...;(M,98)
. :	. :
(m,N(m))	(3,45);...;(m,N(m)-1);...;(M-1,32)
. . .	. . .
(M,1)	(1,16);...;(M,2);(M,3)
. :	. :
(M,N(M))	(2,68);(2,69);...;(M,N(M)-2);(M,N(M)-1)

The data processing described above may be performed conveniently through the repeated execution of certain general procedures. A fundamental procedure NEIGHBOR(m_1,n_1,m_2,n_2) checks if data point (m_1,n_1) is a neighbor of (m_2,n_2) by calculating the Euclidean distance between the GPS position $\mathbf{d}_{n_1}$ in route m_1 with GPS position $\mathbf{d}_{n_2}$ in route m_2. If the distance is less than D meters, then the procedure returns a TRUE value; otherwise it returns a false value. Using this procedure, it is straightforward to

devise a procedure ASSOCIATE_ROUTES(m_1,m_2) that calculates, for each data point in route m_1, the list of neighboring points in route m_2. With m_1=m_2, this procedure can be used to generate the initial route neighborhood files. This procedure can also be used to generate the total neighborhood file from the collection of route neighborhood files by calling the procedure for all cases where $m_1 \neq m_2$ and adding the results of each call to the total neighborhood file. Note that since ASSOCIATE_ROUTES is symmetric, i.e. ASSOCIATE_ROUTES(m_1,m_2) = ASSOCIATE_ROUTES(m_2,m_1), half of the distance calculations need not be performed.

A new route M+1 can be added to the total neighborhood file by calling ASSOCIATE_ROUTES(M+1,m) for all m, and also calling ASSOCIATE_ROUTES(m,M+1) for all m. The first series adds to the new route all neighbors from all existing routes, while the second series of calls adds to the existing routes the neighbors in the new route. Similarly, any route m can be deleted from the total neighborhood file by removing all data points (m,1),...,(m,N(m)) and removing all references to these data points which may be contained in the total neighborhood lists of the data points for the other routes.

GEOGRAPHIC BINNING

The binning procedure uses the contents of the total neighborhood file to construct a collection of geographical bins that represent the area covered by the routes. A bin is defined to be a contiguous geographical region corresponding to a portion of one or more routes. The binning step constructs a collection of bins that correspond to the trajectories of the routes. This collection of bins is a basic component of the final calibration table.

Bins are created sequentially as follows. Initially, all the points in all the routes are tagged as unbinned. A current route variable is initially set to be the first route, and a current point in the current route is initially set to be the initial point in the route. Next, a bin is created that covers a sequence of points starting with the current point and ending with the last successive point in the route that is still within a minimum binning distance from the current point. The bin is assigned a bin location and a signature based on the signatures and locations of the points in the bin, as will be described in more detail below. After the bin is created, the current point is the first point along the route outside the bin. This point becomes the first point for the next bin, and a new bin is created. Bins are successively created along the route in this way until no points remain in the route. After the first route is binned, the current route is then incremented and the binning is repeated in the same manner

for the next route. When all routes have been binned in this way, the binning procedure is completed.

The step of creating a single bin is performed as follows. An initial bin point is set to be the current point. All the neighbors of the current point are identified by inspecting the total neighbor list for the point. These neighbors are the points (from any route) that are within a circular neighborhood of the current point. From the list of these neighbors and the current point itself, all the unbinned points are selected. These selected points will be tagged as binned when the bin is completed, so that they are not included as data for other bins. The covariance matrices of these points are then averaged to form an average covariance matrix **R** associated with the current point. From this average covariance matrix, a covariance signature **U** corresponding to this point is then determined. In the preferred embodiment, the covariance signature **U** corresponding to a covariance matrix **R** is the subspace spanned by the dominant eigenvectors of **R**. In addition, the covariance matrix itself can be used as the signature. In the case where there are no unbinned points among the neighbors of the current point, then no signature value is calculated for the point. In the case where the raw data includes time delay and code correlation data, these are also averaged and included in the signature values for the point.

The current point is then incremented to the next point in the current route. If the current point is less than a predetermined binning distance (e.g., 30 meters) from the initial bin point, then the above procedure is repeated to again produce a signature for this point. As a result, one obtains a series of signature values that correspond to points along the current route within the predetermined binning distance of the initial bin point. In general, the binning distance may be selected to be any value greater than the neighbor distance D. In the preferred embodiment, the binning distance is selected to be approximately 50 meters for typical suburban environments. For dense urban environments, the binning distance is preferably 30 meters, while in rural environments the binning distance is preferably 50 meters or more. The signature values in a given bin are then averaged to form a bin signature, and the corresponding locations are averaged to form an average location. A bin location is selected to be the location of the data point closest to the average location.

In a variation of the above step, each of the bins is divided into sub-bins, as illustrated in FIGS. 8A and 8B. The size and shape of the sub-bins is determined by the location information error. In the case of GPS with differential correction, the sub-bins are preferably squares whose size is about 10 m, and the bins have a size of about 30 m. The locations of raw data points are shown in the figures as empty circles. FIG. 8A shows the vehicle routes as dotted lines. FIG. 8B shows detail of a bin containing nine sub-bins. For each sub-bin an average $\underline{\mathbf{R}}$ of the covariance matrices whose locations are within the sub-bin

is calculated, together with a centroid $\underline{\mathbf{d}}$ of their locations. These sub-bin centroids are shown in FIG. 8B as solid circles. The same procedure is repeated for the bins. That is, for each bin k an average $\mathbf{R}_k$ of the sub-bin covariances $\underline{\mathbf{R}}$ belonging to the bin is calculated, together with a centroid $\mathbf{d}_k$ of the sub-bin locations $\underline{\mathbf{d}}$ in the bin. The centroid for the bin is shown in the figure as a circled 'x' mark. In addition, a bin signature $\mathbf{U}_k$ is calculated from $\mathbf{R}_k$.

This process is continued until the points in the route are all binned. The other routes are then binned in the same way, resulting in a calibration table that incorporates the data from all the routes. In a preferred embodiment adapted for the AMPS standard, distinct calibration tables are constructed for various different frequency bands in use, e.g., one calibration table for each 3 to 6 MHz band of frequency channels. Thus, the calibration table used to derive a location will be selected in dependence upon the frequency of the signal.

Data from a new route can be incorporated into an existing calibration table without repeating many calculations unnecessarily. In particular, data from a new route is used to create a new total neighbor file in the manner already described. All neighbors of the new route, as well as all the points in the new route, are tagged as unbinned. The calibration table can then be updated by executing the binning procedure for the new route.

The optimized calibration table does not contain temporally or spatially redundant data, and contains accurate data due to averaging within each bin. The method also enjoys the advantage that it does not place constraints upon the specific routes that the vehicles take. Those skilled in the art will recognize that the present method produces a contiguous map of a region, providing accuracies often exceeding those of existing survey maps. Thus, the present method has application to accurate map generation, as well as to location determination techniques.

DATA COMPRESSION AND ORGANIZATION

In order to provide a fast real-time location finding system, it is preferable to efficiently store and organize the calibration data. In addition to the signal signature data, it is also preferable to store some precomputed data that allows for more efficient signature matching during real-time location determination. One example of a type of precomputed data is a set of N-dimensional vectors $\mathbf{w}_1,\ldots,\mathbf{w}_N$, each of which is derived from the covariance matrices $\mathbf{R}_1,\ldots,\mathbf{R}_N$ of all N locations. As will be described in more detail later, these vectors can be used in the signature matching procedure to improve matching accuracy. Each vector is defined by $\mathbf{w}_k=[\mathrm{Tr}\{\mathbf{P}_1\mathbf{R}_k\},\ldots,\mathrm{Tr}\{\mathbf{P}_N\mathbf{R}_k\}]^T$, where $\mathbf{P}_i = \mathbf{U}_i\mathbf{U}_i^H$ is the projector onto the subspace of location i. Thus, each component $\mathrm{Tr}\{\mathbf{P}_i\mathbf{R}_k\}$ of the vector measures the extent to

which the covariance matrix $\mathbf{R}_k$ of location k overlaps with the subspace $\mathbf{U}_i$ of location i. This vector can be used to match a real-time covariance matrix $\mathbf{R}$ to a calibrated covariance signature. As will be described in more detail later, a similar vector $\mathbf{w}$ can be calculated from $\mathbf{R}$, and then the quantity $G(\mathbf{w},\mathbf{w}_k) = |\mathbf{w} - \mathbf{w}_k|^2$ is computed to measure the similarity of the real-time signature with calibrated signature k. Because these N-dimensional vectors can take a large amount of storage space, it is desirable to store a more compact representation of their information. It can be shown that $\mathrm{Tr}\{\mathbf{P}_i\mathbf{R}_k\} = \mathbf{p}_i^T\mathbf{r}_k$, where $\mathbf{p}_i$ is a p^2-dimensional vector derived from $\mathbf{P}_i$, and $\mathbf{r}_k$ is a p^2-dimensional vector derived from $\mathbf{R}_k$. Moreover, both $\mathbf{p}_i$ and $\mathbf{r}_k$ have real-value components. Thus, $\mathbf{w}_k=[\mathbf{p}_1^T\mathbf{r}_k,\ldots,\mathbf{p}_N^T\mathbf{r}_k,]^T$. More generally, for any p×p covariance matrix $\mathbf{R}$, one can derive a vector $\mathbf{w}=[\mathbf{p}_1^T\mathbf{r},\ldots,\mathbf{p}_N^T\mathbf{r},]^T$, where $\mathbf{r}$ is a p^2-dimensional vector with real-valued components. In order to reduce the required data storage space as well as the time required to search the database during real-time location-finding, the p^2-dimensional vectors $\mathbf{r}_1,\ldots,\mathbf{r}_N$ are stored instead of the N-dimensional vectors $\mathbf{w}_1,\ldots,\mathbf{w}_N$. In addition, the p^2-dimensional vectors $\mathbf{p}_1,\ldots,\mathbf{p}_N$ are also stored. The vectors $\mathbf{w}_1,\ldots,\mathbf{w}_N$ can then be easily reconstructed in real time as needed.

Another similar technique is based on the following method, which is applicable to more general distance functions (i.e., functions that are not necessarily linear). Perform a singular value decomposition (SVD) of the matrix $\mathbf{W} = [\mathbf{w}_1\ldots\mathbf{w}_N]$. Typically, the SVD of this matrix will have an effective rank dramatically smaller than N. For example, typically only about 100 statistically significant dominant eigenvectors result from an SVD of a matrix $\mathbf{W}$ with N=10,000. These dominant eigenvectors span a subspace $\mathbf{W}_S$ of the matrix $\mathbf{W}$. The projector onto this subspace is $\mathbf{P}_{\mathbf{W}_s} = \mathbf{W}_S\mathbf{W}_S^H$. Now calculate $\underline{\mathbf{w}} = \mathbf{W}_S^H\mathbf{w}$ and $\underline{\mathbf{w}}_k = \mathbf{W}_S^H\mathbf{w}_k$ for k=1,...,N. The vector $\underline{\mathbf{w}}$ is the projection of the N-dimensional vector $\mathbf{w}$ onto the subspace spanned by the dominant eigenvectors of $\mathbf{W}$. Similarly, vector $\underline{\mathbf{w}}_k$ is the projection of the N-dimensional vector $\mathbf{w}_k$ onto the same subspace. The dimension of this subspace is typically about two orders of magnitude smaller than N. Consequently, the vectors $\underline{\mathbf{w}}$ and $\underline{\mathbf{w}}_k$ also have dimension two to three orders of magnitude less than N. Yet, because the other dimensions may be neglected, no significant information is lost by replacing the original N-dimensional vectors by these lower-dimensional vectors. Consequently, the size of the calibration table can be reduced by more than two orders of magnitude by storing these reduced vectors rather than their N-dimensional counterparts.

The matching of the vector $\mathbf{w}$ with vectors in the set of N vectors $\mathbf{w}_1,\ldots,\mathbf{w}_N$ is performed by evaluating $G(\mathbf{w},\mathbf{w}_k)$ for k=1,...,N. It can be seen, however, that

$$G(\mathbf{w},\mathbf{w}_k) = \| \mathbf{w} - \mathbf{w}_k \|^2 = \| \mathbf{W}_S\mathbf{w} - \mathbf{W}_S\mathbf{w}_k \|^2 = \| \underline{\mathbf{w}} - \underline{\mathbf{w}}_k \|^2.$$

Thus, the compact vectors $\underline{\mathbf{w}}$ and $\underline{\mathbf{w}}_k$ can be used directly in the real time calculation, rather than the original vectors. Because the dimensions of $\underline{\mathbf{w}}$ and $\underline{\mathbf{w}}_k$ are much smaller than the dimensions of $\mathbf{w}$ and $\mathbf{w}_k$, the storage requirements are much smaller and the calculation speeds are much faster.

Estimation of Antenna Array Manifold Data

The set of array manifold vectors $\{\mathbf{a}(\theta) : \theta=\theta_1,...,\theta_L\}$ of antenna arrays are conventionally determined empirically through array calibration procedures well-known in the art. The calibration data of the present invention, however, allows the array manifold vectors to be determined without conventional array calibration procedures. Instead, the array manifold vectors can be calculated from the signature calibration table, as follows. As shown in FIG. 9, the service region of an LDA 190 contains a set of calibrated locations, shown in the figure as circled 'x' marks. Consider an angular sector of the service region having an angular width $\Delta\theta$ centered around an angle θ. In the preferred embodiment the value for $\Delta\theta$ is approximately one degree. This particular value, however, is not necessary for the practice of the present invention, and various other values will work as well. Contained within this sector are several calibrated locations $\mathbf{d}_1,...,\mathbf{d}_K$, having corresponding calibrated signature subspaces $\mathbf{U}_1,...,\mathbf{U}_K$. After these subspaces have been identified for a given sector, each subspace $\mathbf{U}_i$ is examined to determine if its largest eigenvector $\mathbf{e}_i$ has a magnitude significantly larger than the other eigenvectors in the same subspace. For example, if the largest eigenvector exceeds the next largest eigenvector by a predetermined factor, then it is considered to be significantly larger than all the other eigenvectors. Preferably, this predetermined factor is at least 2, but is more preferably 10 or more. The result of this examination of the subspaces results in a set of largest eigenvectors. For example, if all the subspaces have significantly large first eigenvectors, then the set of largest eigenvectors will contain one eigenvector from each subspace, $\mathbf{e}_1,...,\mathbf{e}_K$. These eigenvectors are then combined to form an average eigenvector for the sector, $\mathbf{e}_{av}$. Various techniques can be used to determine $\mathbf{e}_{av}$ from $\mathbf{e}_1,...,\mathbf{e}_K$. For example, the K eigenvectors can be stacked in a matrix, and the singular value decomposition of the matrix can be calculated to determine the best rank-1 approximation to the matrix. This best rank-1 approximation is then used as the value for $\mathbf{e}_{av}$. A more accurate estimate of $\mathbf{e}_{av}$ can be determined by using the initial estimate of $\mathbf{e}_{av}$ to exclude some outlying eigenvectors from the set of K eigenvectors and then repeating the procedure. The final value of $\mathbf{e}_{av}$ for the

sector is used as an initial estimate for the array calibration vector $\mathbf{a}(\theta)$ for the sector. Similar estimates are made for all the sectors around the LDA. These estimates then may be improved by imposing a continuity condition on the values of $\mathbf{a}(\theta)$ with respect to θ. The above procedure, therefore, can derive a set of L array calibration vectors $\mathbf{a}(\theta_1),...,\mathbf{a}(\theta_L)$ for a set of L directions $\theta_1,...,\theta_L$ around a LDA.

It should be noted that this technique for generating array calibration vectors from the location database has several important advantages over known methods of generating array calibration vectors. Prior techniques typically require that the array be installed and measured in a special antenna range. The known methods are not useful, therefore, with many existing antenna arrays. The present method, on the other hand, is effective with existing antenna arrays since no restriction is being made on the nature of the array or its supporting structure.

Location Estimation

The approach of the present location determination technique is to measure a real-time signature of a mobile device whose location is unknown, then match the signature with similar signatures in the calibration database. Because the signatures are highly correlated with location, the calibrated locations of the matching signatures will correspond to the location of the mobile device. Various matching procedures can be used that involve different types of signatures, different matching techniques, search optimization algorithms, ambiguity reduction techniques, and so on. The particular combination of techniques used for matching will depend on the type of signature information available, the characteristics of the wireless environment, and other factors.

Covariance Matrix ,Time Delay, and Correlation Matching

In a preferred embodiment, the location of a mobile device in the service area may be determined as follows. Signals originating from the device at an unknown location are received at the LDA, and a signal signature is determined from the signals as described in detail above. In one embodiment of the invention, the signature comprises a covariance signature S that includes a signal covariance matrix $\mathbf{R}$ and a signal subspace $\mathbf{U}$. In another embodiment, the signature includes a signal covariance matrix and signal subspace for each of q multipath parts of the signal, i.e., $\mathbf{S}=\{\mathbf{U}^{(1)},...,\mathbf{U}^{(q)}; \mathbf{R}^{(1)},...,\mathbf{R}^{(q)}\}$. In yet another embodiment, the signature also includes time delay and/or code correlation information. Using the calibration table described above, the signal signature is then compared using a

measure of similarity to a set of calibrated signal signatures which correspond to a set of N calibrated locations.

The measure of similarity between the measured spatial signature $\mathbf{S}$ and a given calibrated spatial signature $\mathbf{S}_k$ may be determined by evaluating a function $D(\mathbf{S},\mathbf{S}_k)$ which maps two signatures to a number indicating their degree of closeness to each other. The value of $D(\mathbf{S},\mathbf{S}_k)$ represents the likelihood that a measured covariance signature $\mathbf{S}$ matches a calibrated signature $\mathbf{S}_k$. Because each signature $\mathbf{S}_k$ corresponds to a known location $\mathbf{d}_k$, the value of $D(\mathbf{S},\mathbf{S}_k)$ also represents the likelihood that the transmitter is at location $\mathbf{d}_k$. According to one suitable definition, $D(\mathbf{S},\mathbf{S}_k)$ is the sum of the traces of the projections of the measured finger covariance matrices $\mathbf{R}^{(1)},...,\mathbf{R}^{(q)}$ onto the corresponding calibrated subspaces, which can be calculated as follows:

$$D(\mathbf{S},\mathbf{S}_k) = \sum_{i=1}^{q} \mathrm{Tr}\, \mathbf{P}_k^{(i)} \mathbf{R}^{(i)},$$

where $\mathbf{P}_k^{(i)}=\mathbf{U}_k^{(i)}[\mathbf{U}_k^{(i)}]^H$ is the projector onto the subspace $\mathbf{U}_k^{(i)}$. In the case where no multipath parts are resolved (i.e., $q=1$), this formula simplifies to $D(\mathbf{S},\mathbf{S}_k) = \mathrm{Tr}\, \mathbf{P}_k \mathbf{R} = \mathbf{p}_k^T \mathbf{r}$, where the vectors $\mathbf{p}_k$ and $\mathbf{r}$ are the p^2-dimensional vectors discussed above in relation to the calibration table data compression. Note that this particular measure does not require that the subspace $\mathbf{U}$ be calculated from $\mathbf{R}$, i.e., it does not require calculating the dominant eigenvectors of $\mathbf{R}$. It will be appreciated that $D(\mathbf{S},\mathbf{S}_k)$ can be defined in many other ways to measure how closely the signal covariance resembles any given calibrated signature. For example, $D(\mathbf{S},\mathbf{S}_k)$ can be defined to be the mean of the squares of the cosines of the principal angles between the subspaces $\mathbf{U}$ and $\mathbf{U}_k$.

In addition to the covariance signature, the signal signature may also include a temporal code correlation for the signal, $\mathbf{C}=[\mathbf{C}^{(1)T},...,\mathbf{C}^{(p)T}]^T$, which can be compared with similar code correlations in the calibration database. This comparison can be made using, for example, a least-squares difference measure. For example, the difference measure between the measured correlation signature $\mathbf{C}=[\mathbf{C}^{(1)T},...,\mathbf{C}^{(p)T}]^T$ and a calibrated correlation signature $\mathbf{C}_k=[\mathbf{C}_k^{(1)T},...,\mathbf{C}_k^{(p)T}]^T$ may be calculated as follows:

$$D'(\mathbf{C},\mathbf{C}_k) = |\mathbf{C}-\mathbf{C}_k|^2 = \sum_{j=1}^{p} |\mathbf{C}^{(j)} - \mathbf{C}_k^{(j)}|^2,$$

where

$$| C^{(j)} - C_k^{(j)} |^2 = \sum^{L}_{i=1} | C^{(j)}(\tau_i) - C_k^{(j)}(\tau_i) |^2.$$

This function $D'(\mathbf{C},\mathbf{C}_k)$ provides a measure of the "distance" between the measured signal code correlation and the code correlation of calibrated location k. It can easily be transformed into a measure of similarity by any of various mappings from $[0,\infty) \rightarrow (0,1]$ that map 0 to 1 (e.g., $f(x)=1/(1+x)$). This separate measure can then be used in addition to $D(\mathbf{S},\mathbf{S}_k)$ in order to improve the accuracy of the match, for example, by keeping only those locations that closely match the measured signal with respect to both code correlation and covariance subspace measures.

Similarly, the temporal delay signature $\tau=[\tau^{(1)},...,\tau^{(q)}]^T$ of the measured signal can be compared to the calibrated temporal delay signature $\tau_k=[\tau_k^{(1)},...,\tau_k^{(q)}]^T$ to provide an additional measure $D''(\tau,\tau_k)$ of difference. For example, one may calculate

$$D''(\tau,\tau_k) = |\tau-\tau_k|^2 = \sum^{q}_{i=1} | \tau^{(i)} - \tau_k^{(i)} |^2.$$

This additional measure of difference (or the corresponding measure of similarity) can then be used in addition to $D(\mathbf{S},\mathbf{S}_k)$ and $D'(\mathbf{C},\mathbf{C}_k)$ in order to further improve the accuracy of the match, for example, by keeping only those locations that closely match the measured signal with respect to all three measures. More generally, it will be appreciated that various combinations of the measures $D(\mathbf{S},\mathbf{S}_k)$, $D'(\mathbf{C},\mathbf{C}_k)$, and $D''(\tau,\tau_k)$ can be used in various ways to select locations appropriately. It will also be appreciated that other formulas may be used to define these functions, provided they measure the degree of similarity or difference between signatures.

In one matching technique of the invention, the measures of similarity and/or difference are used to select a set of most likely locations as follows. First, by evaluating $D(\mathbf{S},\mathbf{S}_k)$ for all N locations, a set of likely locations can be selected by taking, for example, the calibrated locations whose corresponding calibrated spatial signatures are closest to the measured spatial signature. For example, from the locations k=1,...,N, select a subset of M locations

k(1),...,k(M) such that $\{D(S,S_{k(1)}),...,D(S,S_{k(M)})\}$ is the set of M largest values in the set $\{D(S,S_1),...,D(S,S_N)\}$. Alternatively, the set of likely locations can be selected by taking those locations whose corresponding calibrated spatial signatures have at least a minimum degree of similarity to the measured signature. For example, select a subset of locations k(1),k(2),...,k(M) such that for j=1,...M, $D(S,S_{k(j)}) > h$, where h is a predetermined threshold value. This subset of points is illustrated in FIG. 10 as those points above the dotted line corresponding to the value of h.

Another approach to determining a set of likely locations is to consider the topographical structure of the surface defined by z = S(x,y), where the function S is defined at bin location points $(x_k,y_k)=\mathbf{d}_k$ by $S(x_k,y_k)=D(S,S_k)$, and interpolated at other values of (x,y). The locations corresponding to the minima of this surface S should be the most likely locations of the mobile. A systematic search or other analysis of the surface can be used to produce a small set of locations corresponding to distinct minima of the surface. The best match corresponds to the least of these minima. Most probably, the actual location will have both the least minimum, as well as several other minima in close proximity.

Similar selections of likely locations can be made using the difference measures $D'(C,C_k)$ and $D''(\tau,\tau_k)$, noting that these measures are difference measures, while $D(S,S_k)$ is a similarity measure. The selected sets of likely locations using each measure can then be combined or intersected to obtain a single set of likely locations.

SIGNATURE SPECTRUM MATCHING

Another matching technique can be used in addition to the above techniques to further improve the performance of the location finding system. To describe this technique, we first define an N-dimensional vector **w** by

$$\mathbf{w} = [D(S,S_1),...,D(S,S_N)]^T.$$

The vector **w** characterizes how the spatial signature **S** compares to the entire set of calibrated spatial signatures $S_1,...,S_N$. This vector **w** can be thought of as describing a "spectrum" of the signature **S** with respect to the entire set of calibrated signatures $S_1,...,S_N$. This spectrum can be visualized as the graph of the function $D(S,S_k)$ with respect to k, as illustrated in FIG. 10. Similarly, define a set of N vectors $\mathbf{w}_1,...,\mathbf{w}_N$ by

$$\mathbf{w}_k = [D(S_k,S_1),...,D(S_k,S_N)]^T.$$

The vector $\mathbf{w}_k$ characterizes how the calibrated signature S_k compares to the entire set of calibrated spatial signatures $S_1,...,S_N$. In other words, the vector $\mathbf{w}_k$ is a "spectrum" of the calibrated signature S_k with respect to the entire set of calibrated signatures, and corresponds to a graph similar to that shown in FIG. 10 for $\mathbf{w}$.

Because the spectrum $\mathbf{w}$ of a signature contains information about the signature, it can be used for matching. In particular, the spectrum $\mathbf{w}$ of a measured signature can be compared with the spectrum $\mathbf{w}_k$ of each calibrated signature. For example, FIG. 11 shows the graph for the spectrum $\mathbf{w}$ superimposed upon the graphs for spectra $\mathbf{w}_{k(1)}$ and $\mathbf{w}_{k(2)}$. As is evident from the figure, the spectrum $\mathbf{w}_{k(2)}$ is more similar to the spectrum $\mathbf{w}$ than to the spectrum $\mathbf{w}_{k(1)}$. Thus, location k(2) is more likely than location k(1). More generally, by comparing the spectrum $\mathbf{w}$ with each calibrated spectrum $\mathbf{w}_k$, a set of likely locations can be selected, just as the signatures themselves were compared. For example, define a measure of difference G between a real-time signature spectrum $\mathbf{w}$ and a calibrated signature spectrum $\mathbf{w}_k$ using some difference measure. There are many well known techniques for measuring the distance between two vectors. For example, one may define the distance between the vectors by a least-squares difference as follows:

$$G(\mathbf{w},\mathbf{w}_k) = |\mathbf{w} - \mathbf{w}_k|^2 = \sum_{i=1}^{N} |D(S,S_i) - D(S_k,S_i)|^2.$$

A set of likely locations can be selected using this measure of difference alone or in combination with the various measures described above.

The above technique is advantageous and reduces location ambiguity because the comparison between the vectors $\mathbf{w}$ and $\mathbf{w}_k$ includes comparative information from all N components of the vectors, and does not merely select locations based on the components of $\mathbf{w}$ alone. Thus, more information is used to compare the measured signal covariance with the calibrated subspaces, and a more accurate match can be obtained.

Moreover, one can analogously define vectors $\mathbf{w}'$ and $\mathbf{w}''$ from $D'(\mathbf{C},\mathbf{C}_k)$ and $D''(\tau,\tau_k)$, respectively, to obtain functions $G'(\mathbf{w}',\mathbf{w}_k')$ and $G''(\mathbf{w}'',\mathbf{w}_k'')$, respectively. The functions G, G′ and G″ can then be used individually or together to select a set of most likely locations using techniques described above in relation to functions D, D′ and D″. It will be appreciated

that various combinations of the measures D, D′, D″, G, G′, and G″ can be used in various ways to select locations using the techniques described above, or similar techniques. It will also be appreciated that other formulas may be used to define these measures.

CALCULATION OPTIMIZATIONS

It should be noted that, in the case where $D(\mathbf{S},\mathbf{S}_k) = Tr\{\mathbf{P}_k\mathbf{R}\}$, this similarity measure can be easily computed by $D(\mathbf{S},\mathbf{S}_k) = \mathbf{p}_k^T\mathbf{r}$, where $\mathbf{p}_k$ is a p^2-dimensional vector derived from $\mathbf{P}_k$, and $\mathbf{r}$ is a p^2-dimensional vector derived from $\mathbf{R}$. Moreover, both $\mathbf{p}_k$ and $\mathbf{r}$ have real-value components. Thus, $\mathbf{w}_k=[\mathbf{p}_1^T\mathbf{r}_k,...,\mathbf{p}_N^T\mathbf{r}_k,]^T$ and $\mathbf{w}=[\mathbf{p}_1^T\mathbf{r},...,\mathbf{p}_N^T\mathbf{r},]^T$. This technique simplifies the computation of $D(\mathbf{S},\mathbf{S}_k)$ and $G(\mathbf{w},\mathbf{w}_k)$, as well as reducing the amount of storage space required for precomputed values.

With these simplified representations of $\mathbf{w}$ and $\mathbf{w}_k$, the closeness of the measured signature and a calibrated signature can be calculated, as before, with the function $D(\mathbf{w},\mathbf{w}_k)$. This measure, however, was defined using all N components of the vectors. It is desirable, therefore, to simplify the calculation of D to use the simplified representations of the vectors. One such technique for simplifying the calculation of D is as follows. Define the matrices $\underline{\mathbf{P}}^T = [\mathbf{p}_1^T...\mathbf{p}_N^T]$ and $\underline{\mathbf{R}} = [\mathbf{r}_1...\mathbf{r}_N]$. It can then be shown that the N×N calibration table matrix $\mathbf{W} = [\mathbf{w}_1...\mathbf{w}_N]$ is given by $\mathbf{V} = \underline{\mathbf{P}}\ \underline{\mathbf{R}}$, and that

$$G(\mathbf{w},\mathbf{w}_k) = |\mathbf{w} - \mathbf{w}_k|^2$$
$$= |\underline{\mathbf{P}}\,\mathbf{r} - \underline{\mathbf{P}}\,\mathbf{r}_k|^2$$
$$= |\mathbf{Q}\,\mathbf{r} - \mathbf{Q}\,\mathbf{r}_k|^2,$$

where $\mathbf{Q}^T\mathbf{Q}$ is the Cholesky factorization of $\underline{\mathbf{P}}^T\underline{\mathbf{P}}$. Since $\mathbf{Q}$ is a $p^2\times p^2$ square matrix, and since both $\mathbf{r}_k$ and $\mathbf{r}$ are p^2-dimensional vectors, it is very simple to store $\mathbf{Q}$ and $\mathbf{Q}\mathbf{r}_k$, and to compute $G(\mathbf{w},\mathbf{w}_k) = |\mathbf{Q}\,\mathbf{r} - \mathbf{Q}\,\mathbf{r}_k|^2$. In a typical embodiment, with p=6 and N=10,000, this technique provides more than two orders of magnitude savings in storage and computation.

In an alternate technique, a vector $\underline{\mathbf{w}} = \mathbf{W}_S^H\mathbf{w}$ is the projection of the N-dimensional vector $\mathbf{w}$ onto the subspace $\mathbf{W}_S$ spanned by the dominant eigenvectors of $\mathbf{W} = [\mathbf{w}_1...\mathbf{w}_N]$. Similarly, vector $\underline{\mathbf{w}}_k = \mathbf{W}_S^H\mathbf{w}_k$ is the projection of the N-dimensional vector $\mathbf{w}_k$ onto the same subspace. These vectors have dimensions significantly smaller than N, and thus

require less storage space. The matching of the vector $\mathbf{w}$ with vectors in the set of N vectors $\mathbf{w}_1,...,\mathbf{w}_N$ is performed by evaluating $G(\mathbf{w},\mathbf{w}_k)$ for k=1,...,N. It can be seen, however, that

$$G(\mathbf{w},\mathbf{w}_k) = |\ \mathbf{w} - \mathbf{w}_k\ |^2 = |\ \mathbf{W}_S\mathbf{w} - \mathbf{W}_S\mathbf{w}_k\ |^2 = |\ \underline{\mathbf{w}} - \underline{\mathbf{w}}_k\ |^2.$$

Thus, the computation of $G(\mathbf{w},\mathbf{w}_k)$ is significantly simplified.

ANGULAR ENERGY DISTRIBUTION MATCHING

Another approach to signature matching that can be used separately or together with the above techniques involves the use of array manifold vectors $\{\mathbf{a}(\theta)\}$. These vectors can be determined using signature calibration information, as described above, or by other known techniques. Once these vectors are known, they can be used for locating a mobile device, as follows. The covariance matrix $\mathbf{R}$ for the device is measured as described above, and an angular energy distribution $B(\theta)$ for the signal is calculated for each value of θ. Typically, there are approximately 360 values. In the preferred embodiment, the angular energy distribution is calculated with a beamforming metric, as follows:

$$B(\theta) = \mathbf{a}(\theta)^H\ \mathbf{R}\ \mathbf{a}(\theta).$$

Alternatively, any high resolution angular energy distribution metric can be used, such as the MUSIC metric,

$$B(\theta) = \mathbf{a}(\theta)^H\ \mathbf{U}\mathbf{U}^H\ \mathbf{a}(\theta),$$

where $\mathbf{U}$ is the matrix of the dominant eigenvectors of $\mathbf{R}$. A similar function is precomputed in advance for each of the calibrated signal covariance matrices $\mathbf{R}_1,...,\mathbf{R}_N$. One then obtains a set of N angular energy distribution functions $B_1(\theta),....,B_N(\theta)$ corresponding to the set of N calibrated locations. For the beamforming metric, one calculates

$$B_k(\theta) = \mathbf{a}(\theta)^H\ \mathbf{R}_k\ \mathbf{a}(\theta).$$

Alternatively, for the MUSIC metric one calculates

$$B_k(\theta) = a(\theta)^H U_k U_k^H a(\theta),$$

where U_k is the matrix of the dominant eigenvectors of R_k. This set of functions $B_1(\theta),...,B_N(\theta)$ is preferably calculated in advance and stored in the calibration database.

In a preferred embodiment, a set of likely locations is determined by comparing the real-time angular energy distribution $B(\theta)$ of the signal from the mobile device with the calibrated angular energy distributions $B_1(\theta)$, ..., $B_N(\theta)$. In the preferred embodiment, these distributions are compared using a statistical measure $\underline{G}$ to measure the similarity between B and each of the calibrated distributions $B_1,...,B_N$. For example, the measure $\underline{G}$ can be defined by the squared difference:

$$\underline{G}(B, B_k) = \sum_\theta | B(\theta) - B_k(\theta) |^2,$$

where the sum is over all angles θ=1,...,360. Alternatively, the metric $\underline{G}$ can be defined as the Kullback-Liebler distance or other metric. Using this similarity measure $\underline{G}$, the set of likely locations is then selected using techniques such as those already described above for the similarity measures D, D′, D″, G, G′, and G″.

ADDITIONAL AMBIGUITY REDUCTION TECHNIQUES

In addition to the above techniques which use various types of signature analysis to resolve ambiguities and improve matching, various other techniques can be used for resolving ambiguities and improve the accuracy of the location determination technique.

Map Comparisons

One technique for reducing ambiguities is to compare the computed likely locations with locations on a map. For example, if the mobile device is known to be moving, it can be assumed that it is most likely in a vehicle constrained to known roads. Thus, any off-road locations can be eliminated or assigned lower likelihoods, especially if the mobile has a large velocity.

Tracking

Another technique for resolving ambiguity is a motion tracking system that associates sets of likely locations measured over the course of several seconds or minutes. Using realistic assumptions about the possible changes in phone location over the course of time, the ambiguities in location can be reduced or resolved. For example, it is very unlikely that a phone that has been located in one localized region of the service area will suddenly move to another location several miles away. Motion continuity constraints, in other words, can be used to eliminate or reduce the likelihood of some locations.

A preferred tracking technique will now be described in relation with FIG. 12. The technique includes constructing trajectories, called tracks, from the sets of likely locations over the course of time. These tracks are illustrated in the figure by solid curves. The technique also includes updating the tracks when each consecutive set of likely locations is obtained, and determining the likelihoods of the various tracks. Similar techniques are well-known in the art of military target tracking. The current tracks at any given point in time have an end point corresponding to the most recent location of the track, and a predicted next point. The end points are shown in the figure as solid circles at the right end of the tracks, while the predicted next points are shown as empty circles. Predicted paths, shown as broken lines, connect the end points with the predicted next points. A set of points corresponding to the next measured set of likely locations is then obtained using the matching techniques described above. These measured points are shown as disconnected solid circles. Typically, in the next measured set of likely locations, some points will be close to the predicted next points of the tracks and some others will not be close. Clearly, the points that are close to present tracks are more likely to correspond to the actual location.

Given a set of tracks and a set of likely locations, calculate for each track a predicted next location and compute its variance (e.g., using the well-known Kalman filter). Using the likelihoods of the data points in the track, calculate the a priori probability of the track. Next, among all the possible pairwise associations between predicted next locations of tracks and the measured set of likely locations, determine the association that maximizes the a posteriori probabilities of the pairwise associations, i.e. find the best match between the predicted track locations and the actual locations. Eliminate associations whose distance is greater than a predetermined association threshold. Terminate any tracks that have a predetermined number of consecutive association failures. For any unassociated locations, initiate new tracks. New tracks are considered tentative until they have been confirmed. A tentative track is confirmed when I locations are associated to it out of J consecutive attempts. The integers I and J are design parameters that are selected in dependence upon the particular desired system tracking performance. All the tracks are then filtered using the well-known Kalman filter. The most likely location of the mobile device is the new (filtered) endpoint of the most likely track. Typically, there will be various short tracks corresponding to erroneous

locations, and one longer track corresponding to the correct location. Other tracking methods may be used to achieve similar results. In addition, this tracking method may be used alone or in conjunction with other methods of reducing ambiguity.

Multi-Site Data

Another technique for resolving ambiguity is to combine sets of likely locations obtained from multiple LDAs. This technique makes use of a set of several LDAs in communication with each other, e.g., through a central hub. As illustrated in FIG. 13, a hub 192 collects location information over communication lines 194 connected to multiple LDAs 196, 198, and 200. Each LDA receives signals from a mobile 202, estimates its current location, and transmits these location estimates over conventional communication lines 194 to the hub 192. Thus, location estimates are derived independently by the multiple LDAs and sent to the hub. In the case where multiple LDAs have determined sets of likely locations for the same mobile device, the hub can intersect or otherwise combine these sets to improve the accuracy of and confidence in the location estimates.

The combination of the sets of likely locations from the distinct LDAs reduces the ambiguity because the propagation paths of the signal to the different LDAs are different and, consequently, only the true location is likely to be common to all sets. As a result, this technique proves highly effective in reducing location ambiguity. It is significant to note that no temporal synchronization between LDAs is necessary because the location information is determined independently at each of the separate LDAs. Conventional location determination techniques, in contrast, often require precise synchronization at multiple base stations in order to measure differential times of arrival between signals received at the different base stations. Such techniques also require high bandwidth communication to send batches of raw timing data to a central hub for location determination computations. The present technique, in contrast, computes the locations from the raw data at each LDA and only sends a small set of likely locations to the hub. Thus, no high speed or high bandwidth communication lines are required.

In an alternate version of multi-site ambiguity reduction, rather than sending likely location data from the LDAs to the hub, signal covariance matrices are sent to the hub and signature matching is performed by the hub rather than by each LDA. In this method, the calibration data for each LDA is stored at the hub rather than at each LDA. This system architecture reduces the hardware cost of the LDAs. The hub, on the other hand, is preferably provided with one or more very powerful computers, which it uses to perform signature matching for all the LDAs it serves. One approach to performing this matching simply uses the matching process that would have been used by each LDA, then combines the independently derived likely locations to reduce ambiguity, just as described above. Alternatively, the hub can take

advantage of the fact that it has signature data from multiple LDAs to perform more sophisticated matching. One technique for implementing this idea is as follows. Let $G_1(k)$ be a difference measure between a signature measured at a first LDA and the calibrated signature corresponding to location k for the same LDA. For example, if $\mathbf{w}$ and $\mathbf{w}_k$ are the measured and calibrated spectra at this LDA, then $G_1(k)$ might be defined by $G_1(k) = G(\mathbf{w},\mathbf{w}_k)$. One can also define $G_1(k)$ using various other measures described above. Similarly, define $G_2(k)$ to be a difference measure between a signature measured at a second LDA and the calibrated signature corresponding to the same location k for this second LDA. Now, rather than independently selecting sets of likely locations using $G_1(k)$ and $G_2(k)$ separately, one can select a set of likely locations in one step using $G_1(k)$ and $G_2(k)$ together. For example, select those locations k such that $G_1(k) + G_2(k) < F$, where F is a predetermined difference threshold. Alternatively, one could select the set of M locations $k(1),...,k(M)$ having the smallest sums $G_1(k) + G_2(k)$ of all the locations. Because this technique simultaneously compares the signals with both the calibrated databases, it provides a higher degree of accuracy and ambiguity reduction than the technique of comparing signals with the databases independently. It will be appreciated by those skilled in the art that this technique generalizes in a straightforward way to three or more base stations. It will also be appreciated that the transmission of covariance matrices from the LDAs to the hub does not require large bandwidth since each covariance matrix is typically only a six-by-six matrix, and is typically sent once every 5 seconds.

EFFICIENT SEARCHING TECHNIQUES

In order to improve the computational efficiency of the real-time signature matching, the calibration data can be organized, and a searching technique can be used to efficiently search the organized calibration information. According to one such technique, a hierarchical tree structure, as shown in FIG. 14, is associated with the set of N calibrated locations. The tree structure is composed of a number of nodes, shown as circles in the figure. Each node is connected to one higher level node (except for the top node, shown containing the numeral "1".) and each node is also connected to a number of lower level nodes (except the bottom nodes, shown containing the numerals "1/1024"). For simplicity of illustration, the tree in the figure has only two branches descending from each node. Preferably, there are actually 4 to 16 branches descending from each node, and 3 to 6 levels of nodes. The leaf nodes of the tree at the bottom level have no lower level nodes.

Using well-known data clustering methods, each location k is assigned to at least one leaf node at the lowest level of the tree. Typically, each leaf node contains 10 to 30 locations. A node at the second-lowest level contains the union of the points contained in the lower-level

nodes connected to it. A similar relationship holds between other nodes in the tree. Thus, the highest node contains the indices of all N locations in the calibration table, while the second-highest nodes contain (not-necessarily disjoint) subsets of these N indices. As discussed earlier, signatures preferably are matched by comparing the spectrum $\mathbf{w}$ of a measured signature with the spectrum $\mathbf{w}_k$ of calibrated signatures. This tree-searching technique, however, can be used with other matching techniques as well. The following description of the tree search, however, assumes for the sake of illustration that the matching is performed using the signal spectrum.

Each node q of the tree has associated with it a mean spectrum vector $\mathbf{w}_{av}(q)$ calculated by averaging all the vectors $\mathbf{w}_k$ corresponding to locations in the node q. Also associated with the node q are precomputed node parameters

$$G_{max}(q) = \max \{ G(\mathbf{w}_{av}(q),\mathbf{w}_k) \text{ such that location k is in node q}\},$$
$$G_{min}(q) = \min \{ G(\mathbf{w}_{av}(q),\mathbf{w}_k) \text{ such that location k is in node q}\},$$

Each leaf node also has associated with it a set of precomputed distances $G(\mathbf{w}_i,\mathbf{w}_j)$, for all pairs $\mathbf{w}_i,\mathbf{w}_j$ in the node such that $i > j$. These precomputed values are preferably stored with the calibration table data and updated whenever the table is recalibrated.

Using this hierarchical tree-structure and associated data, the process of searching the calibration database for a matching signature is made much more efficient. The preferred searching technique has two phases. The tree search procedure used in the first phase of the matching is an adaptation of the well-known branch and bound algorithm, which traverses the tree and efficiently eliminates all nodes from the search that cannot contain the best match. The elimination of nodes from the search is guided by the following rule. A node q is eliminated if either

$$G(\mathbf{w}, \mathbf{w}_{av}(q)) - G_{max}(q) > B$$

or if

$$G_{min}(q) - G(\mathbf{w}, \mathbf{w}_{av}(q)) > B$$

where B is the distance from $\mathbf{w}$ to the best matching vector among the vectors considered thus far in the tree.

Once a leaf node is reached, an efficient search technique is used to perform the matching within the node. In this technique, the precomputed values $G(\mathbf{w}_i,\mathbf{w}_j)$ for the node are used to quickly eliminate vectors within the node. Note that the storage requirement for the

precomputed distances $G(\mathbf{w}_i,\mathbf{w}_j)$ is quadratic in the number of points in the leaf node. Consequently, the number of points in the leaf nodes is preferably kept small in order to minimize storage requirements. In the preferred embodiment, the number of points in a leaf node is typically between 10 and 30. The elimination of points from the search process within a leaf node q is performed using the following rule. A location $\mathbf{d}_k$ is eliminated if

$$| G(\mathbf{w}, \mathbf{w}_{av}(q)) - G(\mathbf{w}_k, \mathbf{w}_{av}(q)) | > B,$$

or if

$$| G(\mathbf{w}_s,\mathbf{w}_k) - G(\mathbf{w}_s,\mathbf{w}) | > B,$$

where B is the distance from $\mathbf{w}$ to the best match among the set of vectors considered so far in the tree, and where s indexes a special point $\mathbf{d}_s$ selected within the leaf node. Note that this rule does not require any new distance computations beyond the single distance $G(\mathbf{w}_s,\mathbf{w})$. Thus, to quickly eliminate as many points as possible, it is important to choose $\mathbf{d}_s$ so that the distance between $\mathbf{w}_s$ and $\mathbf{w}$ is small. In the preferred embodiment, the index s for $\mathbf{d}_s$ is determined by the following approximation criterion:

$$s = \arg\min_s \max_k \{ | G(\mathbf{w}_s,\mathbf{w}_k) - G(\mathbf{w}_s,\mathbf{w}) |^2 \},$$

or

$$s = \arg\min_s \{ \sum_k | G(\mathbf{w}_s,\mathbf{w}_k) - G(\mathbf{w}_s,\mathbf{w}) |^2 \},$$

where the $\max_k$ and the $\sum_k$ are evaluated over all indices k corresponding to points considered so far in the node, and the $\arg\min_s$ function ranges over all indices s corresponding to points not considered yet in the node. This process of point elimination is continued until all the points in the leaf have been either eliminated or considered.

It should be noted that this efficient matching procedure can be easily extended to search for a multiple number of best locations. Alternatively, it can be extended to search for a set of likely locations that satisfy various other criteria. For example, one criterion for a likely location $\mathbf{d}_k$ is that $G(\mathbf{w}_k,\mathbf{w}) < \alpha B$, where B is the distance to the best match and α is a constant greater than 1.

Applications of Location Information

The location determination techniques of the present invention provide real-time location information of mobile devices with accuracy and confidence higher than any similar land-based systems. In addition, in contrast with other systems, the present techniques do not require multiple base stations to determine a location of a mobile device, nor do the present techniques require modification of existing communication system base stations or mobile devices. The present techniques also have the unique advantage that they provide accurate location information in severe multipath environments. Moreover, the accuracy of the present system actually improves in the presence of severe multipath. These and other advantages of the present invention provide a unique and practical solution to the long-standing problem of location determination in wireless communication systems. For the first time, accurate location information can be determined in severe multipath environments and in environments where only one base station can receive a mobile device signal. In addition, this accurate location information can be provided without expensive and elaborate modification or replacement of the existing communications network hardware. This significant improvement in location determination, therefore, provides for the first time techniques that enable the widespread practical realization of many location-based services that benefit the mobile device users, the wireless communications provider, and third parties.

Many useful applications of real time location information have long been known, but have not been commercially realized due to the technical and economic difficulties in obtaining accurate location information. Because the present invention overcomes these difficulties, these desirable applications can now be realized. Although these applications have been described in the prior art in relation to other location determination techniques, to the extent that they are independent of these particular techniques, they may be adapted to make use of the location determination technique of the present invention. In other words, the substitution of the present location finding technique in the place of a prior location finding technique in previously known applications is in most cases an obvious and straightforward modification. It should be noted, however, that because the present technique is based upon a unique approach to the location finding problem, new and useful applications of location information may be conceived that have not been previously known at all.

Wireless Subscriber Services

The accurate and reliable location information provided by the present invention can be used to provide many important services to the mobile device users.

Emergency Dispatching

In the event that a wireless device user places a call (e.g., a 911 call) to report an emergency situation, the location of the user can be automatically determined and quickly transmitted to the appropriate authorities to ensure a fast response. In particular, the location information derived from one or more LDAs or from an LDA hub is stored in a real-time location database that is accessible to an emergency dispatcher, e.g., via a computer network connection. Because the caller's location can be tracked in real-time, dispatchers and dispatched emergency vehicles can monitor the location of a user who is not stationary.

Location-Based Service Information

Location information also can be used for location-enhanced information services, e.g., for providing navigational directions and/or traffic condition information to a motorist, or to provide information to a caller about nearby restaurants, gas stations, automatic teller machines, parking lots, movie theatres, and so on. This application can be implemented, for example, by allowing an information vendor to access the real-time location database of callers. The caller location information can then be used to access a location-indexed database of services. The information vendor may be an automated system, e.g., a website or audio information system.

Vehicle Fleet Management

The locations of commercial vehicle fleets can be tracked in real time in order to assist in the management of the vehicles. For example, automatic smart vehicular scheduling can use real-time location information to optimize the use of vehicles based on vehicle locations and the locations of pick-ups or deliveries. The location information can also be used to optimize the routes taken by individual vehicles based on current traffic conditions, road condition, and road construction. Over the long term, location information can also be used to monitor vehicle use and schedule vehicle maintenance.

Tracking People and Objects

Location information also can be used for remotely monitoring the location of children, patients, or other individuals. The person need only wear a small micro-transmitter "tag" that periodically transmits a sufficiently powerful signal to be received by an LDA. A similar "tag" can be attached to objects such as automobiles to assist in locating them in the event that they are lost or stolen. In one possible implementation of this application, the location of the "tag" can be accessed by an authorized subscriber to the service via a website or by telephone.

WIRELESS PROVIDER SERVICES

A wireless communication provider can make use of location information to manage wireless networks individually and collectively. For example, location information can be used to assist in hand-off between cells, for automatic trunking, for channel borrowing, for channel capacity optimization, to more efficiently allocate cellular frequencies, and to increase the capacity of the network. The location information can also be used to actively monitor and/or manage the wireless traffic in a network, e.g., to help determine locations where calls are dropped, and to help determine where new base stations are needed. Location information also can be used for location-based billing of cellular calls and to help combat cellular fraud. It also can be used in conjunction with antenna selection techniques to improve individual cell efficiency and capacity. Since antennas at existing cellular base stations have differing directional responses, this technique allows more efficient assignment and use of frequency channels within presently existing cells. In particular, by using location information to pool channels among different sectors, the base station can reduce blocking and increase trunking efficiency.

In addition, location information provided by the present method can be used to improve the quality of and extend the range of existing base stations by beamforming in both receiving and transmission. For receiving, one can use the matrix A stored in the calibration table to compute the optimal beamformer. For transmission, one has to compute first the corresponding A matrix for the transmission frequency. This can be done as part of the calibration process by probing techniques, i.e., by using several different weight vectors and computing the received signal at the mobile. The matrix A can then be calculated from this data off-line.

Also, the location finding method can be used to implement location division multiple access (LDMA) to increase the capacity of cellular systems by allowing several phones to use the same frequency in the same base station service area. In contrast to switched beam techniques which divide the service area into large spatial sectors, LDMA divides the service area into small localized subcells. The subcells are based on the computation of signal signatures, such as the signal subspace. The shapes and sizes of the localized subcells are determined by the multipath reflectors in the environment. In particular, each subcell is characterized by a unique signal signature, so that transmitters in different subcells display distinct signal signatures. Accordingly, the present technique of LDMA often permits the isolation of interferers which might otherwise be in the same switched beam sector.

The present invention has an important advantage over spatial division multiple access (SDMA) techniques in that location-based computations can be done off-line once the

calibration database for the base station has been determined. Frequency assignment and beamforming can then be performed quickly in real time since a large amount of preprocessing has been performed in advance. Conventional SDMA techniques, in contrast, require complex computations to be performed in real time.

To implement this scheme, the beamforming in both the reception and transmission is computed from the whole set of **A** matrices corresponding to all the phones using the frequency. To compute the locations of all the users, the preferred embodiment is modified to incorporate techniques, such as those based on high order statistics, that can blindly estimate the array vectors in the presence of statistically independent interferers. This step should be carried out on every batch of 100 samples spanning a 1 ms sampling interval. Beamforming techniques such as this will improve signal to noise ratios, increase the overall capacity of the cellular network, and allow a higher density of base stations to be deployed. Network management techniques are used to coordinate nearby base stations to efficiently share frequencies based on the locations of a set of transmitters.

The foregoing system also provides a means for trouble shooting a base station. The array response matrix **A** can be used to continually monitor the performance of the array of antennas and/or equipment at the base station. For example, sudden and dramatic changes in the elements of the **A** matrix for all locations are likely due to hardware damage to the base station. An examination of the **A** matrices can be used to isolate and identify the damage. Smaller changes in **A** may indicate minor hardware changes in the base station and/or changes in the propagation environment. A comparison of such changes in the array response at one base station with those at another can be used to determine whether or not the changes are isolated to one station or common to all stations in the shared environment.

THIRD-PARTY SERVICES

The location information provided by the present invention can be used by various third-party entities in advantageous ways. For example, highway safety authorities can monitor metropolitan freeway traffic flow in real time, and obtain location-specific information about current traffic flow, congestion, likely accidents, etc. This information can be used to automatically display messages to motorists advising them to take alternate routes to avoid troubled areas, and/or to automatically dispatch police or fire vehicles to investigate likely traffic accidents. This traffic information can also be sent or made available directly to motorists whose locations indicate that they may be affected by the conditions.

CLAIMS

What is claimed is:

1. A method for location estimation in a wireless communication system comprising a mobile device and a location determination apparatus, the method comprising:

a) coherently receiving at the location determination apparatus a set of p signals using p receivers coupled to an antenna array comprising p antenna elements;

b) calculating at the location determination apparatus a signal signature for the mobile device from the coherently received set of p signals, wherein the signal signature characterizes a spatial channel between the mobile device and the location determination apparatus; and

c) selecting a set of likely locations from a predetermined set of calibrated locations corresponding to a predetermined set of calibrated signal signatures, wherein selecting the likely locations comprises matching the signal signature with similar calibrated signal signatures.

2. The method of claim 1 wherein the signal signature comprises multipath information of the spatial channel.

3. The method of claim 1 wherein calculating the signal signature comprises collecting a batch of p-dimensional signal vectors derived from the received signals, wherein the p-dimensional signal vectors represent signals originating at the mobile device.

4. The method of claim 3 wherein calculating the signal signature further comprises calculating a signal covariance matrix $\mathbf{R}$, wherein the calculating comprises combining outer products of the p-dimensional signal vectors.

5. The method of claim 1 wherein calculating the signal signature comprises combining signal covariance matrices derived from outer products of the p-dimensional signal vectors.

6. The method of claim 5 wherein combining the signal covariance matrices comprises forming a linear combination of signal covariance matrices weighted by factors derived from an estimated velocity of the mobile device.

7. The method of claim 5 wherein the combining comprises estimating a velocity of the mobile device from a pair of recently measured covariance matrices.

8. The method of claim 1 wherein calculating the signal signature comprises comprises resolving each of the p signals into q multipath parts, and calculating q signal covariance matrices for the q multipath parts.

9. The method of claim 1 wherein calculating the signal signature comprises resolving each of the p signals into q multipath parts, estimating q relative temporal delay times of the q multipath parts, and forming a temporal delay signature from the q relative temporal delay times.

10. The method of claim 1 wherein calculating the signal signature comprises deriving p code correlations from the p signals and forming a code correlation signature from the p code correlations.

11. The method of claim 1 wherein the selecting comprises evaluating a function measuring the similarity between the signal signature and a calibrated signal signature.

12. The method of claim 11 wherein evaluating the function comprises computing a trace of a projection of a signal covariance matrix onto a calibrated covariance matrix subspace.

13. The method of claim 1 wherein the calibrated signal signatures comprise a signature chosen from the group consisting of a covariance matrix signature, a temporal delay signature, a code correlation signature, and an angular energy distribution signature.

14. The method of claim 1 wherein the selecting comprises calculating signature similarity functions for multiple signature types and combining the calculated functions.

15. The method of claim 1 wherein the calibrated signal signatures comprise a set of calibrated vectors $\mathbf{w}_k$, wherein each calibrated vector $\mathbf{w}_k$ measures a degree of similarity between a calibrated signal covariance matrix $\mathbf{R}_k$ and a collection of calibrated signal covariance matrices, and wherein the signal signature comprises a vector $\mathbf{w}$ measuring degree of similarity between a signal covariance matrix and the collection of calibrated signal covariance matrices.

16. The method of claim 15 wherein selecting comprises calculating the difference between the vector $\mathbf{w}$ and a calibrated vectors $\mathbf{w}_k$.

17. The method of claim 15 wherein the dimensions of w and w_k are both equal to p^2.

18. The method of claim 1 wherein the selecting comprises searching nodes of a tree-structure indexing the calibrated signatures.

19. The method of claim 18 wherein the searching comprises eliminating nodes of the tree-structure, and searching calibrated locations within remaining nodes.

20. The method of claim 1 wherein the selecting is performed by the location determination apparatus.

21. The method of claim 1 further comprising communicating the calculated signal signature to a hub, and wherein the selecting is performed at the hub, preferably using supplementary signal signatures communicated from additional location finding apparatuses.

22. The method of claim 1 further comprising modifying the set of likely locations based on a comparison of the likely locations with geographical information.

23. The method of claim 1 further comprising tracking subsequent sets of likely locations.

24. The method of claim 1 further comprising updating the predetermined set of calibrated signal signatures based on the signal signature and known geographic information.

1/13

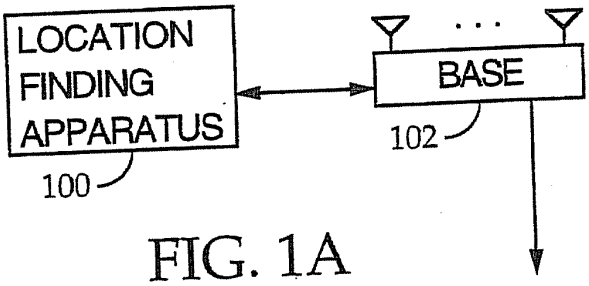


FIG. 1A

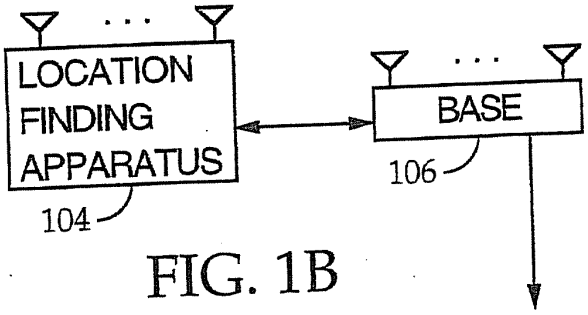


FIG. 1B

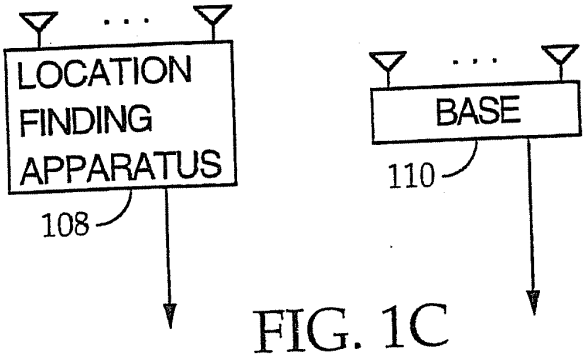


FIG. 1C

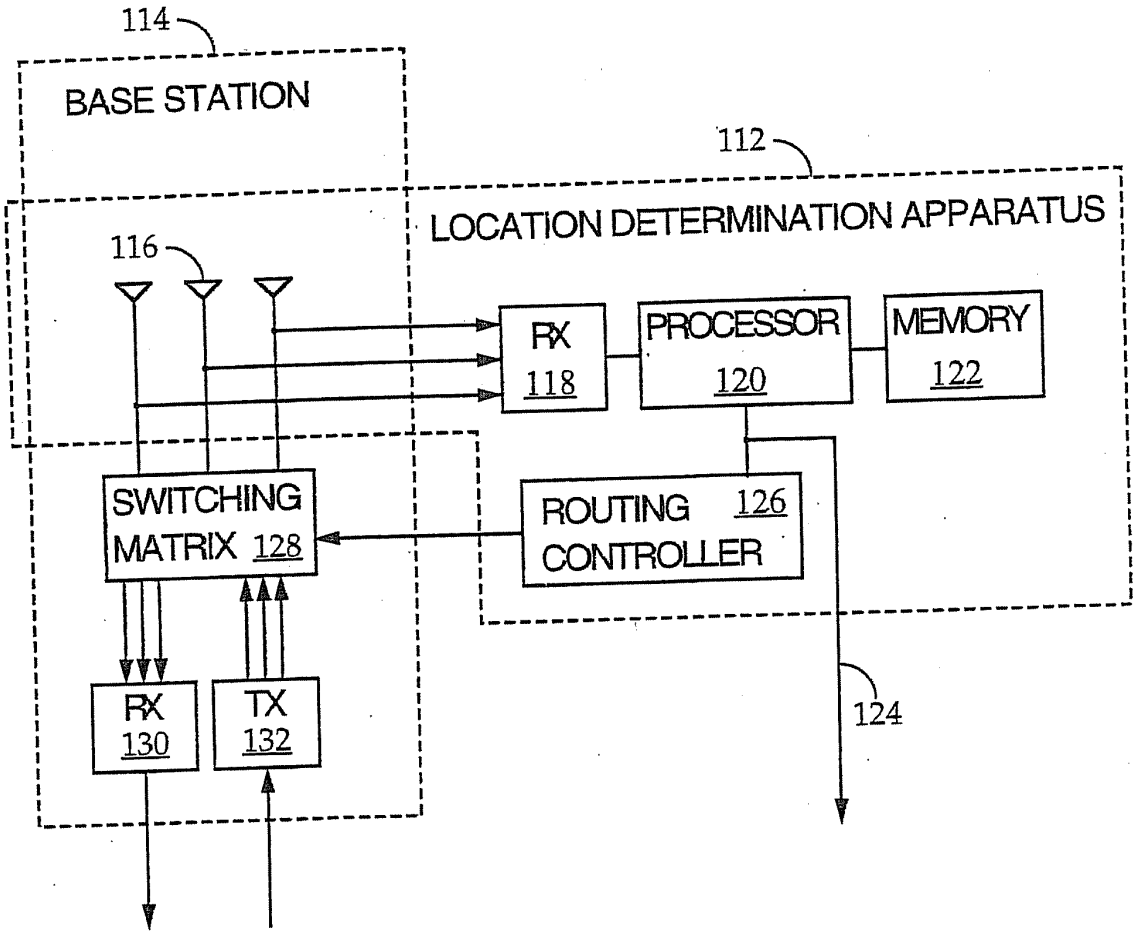

114
BASE STATION
112
LOCATION DETERMINATION APPARATUS
116
RX
118
PROCESSOR
120
MEMORY
122
SWITCHING
MATRIX 128
ROUTING 126
CONTROLLER
RX
130
TX
132
124

FIG. 2

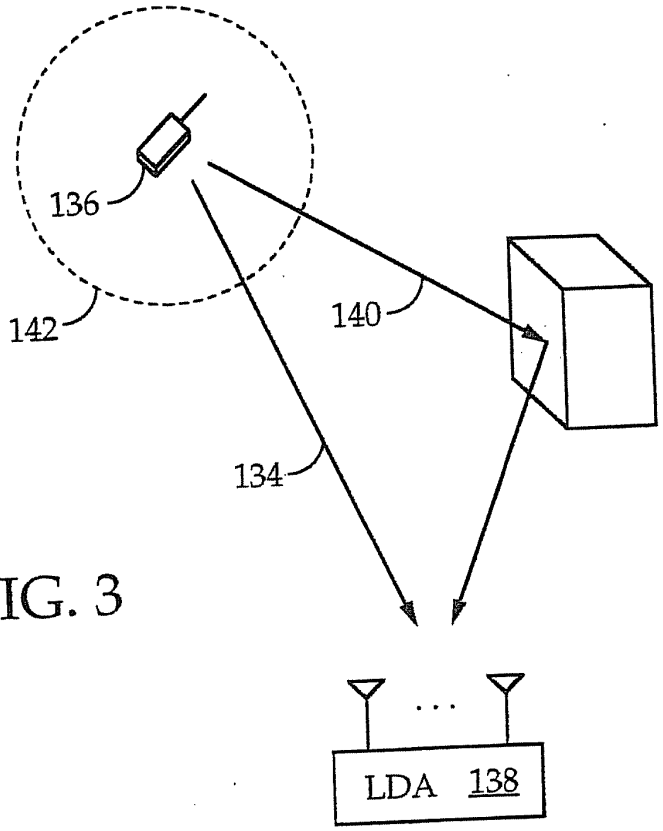


FIG. 3

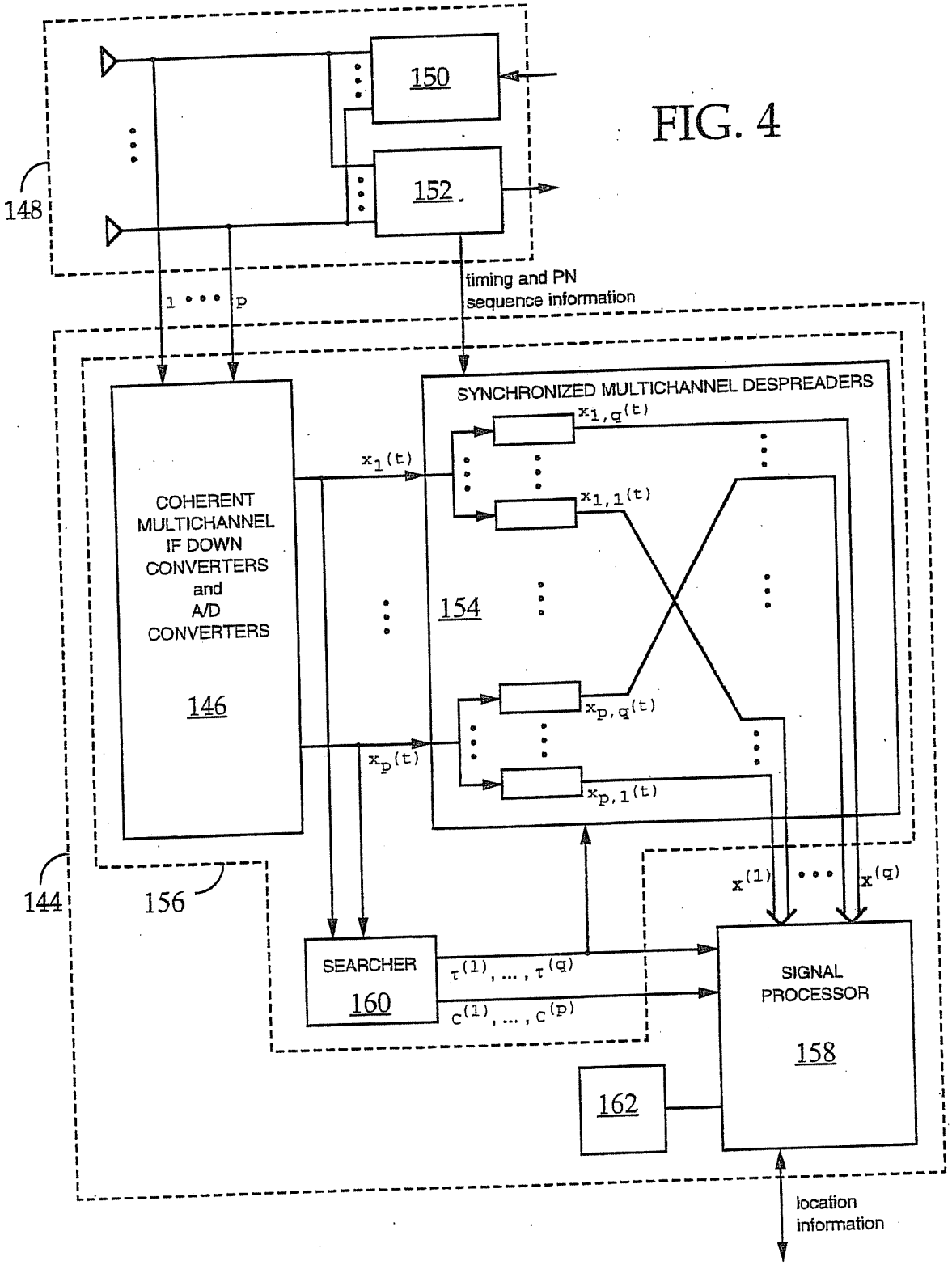
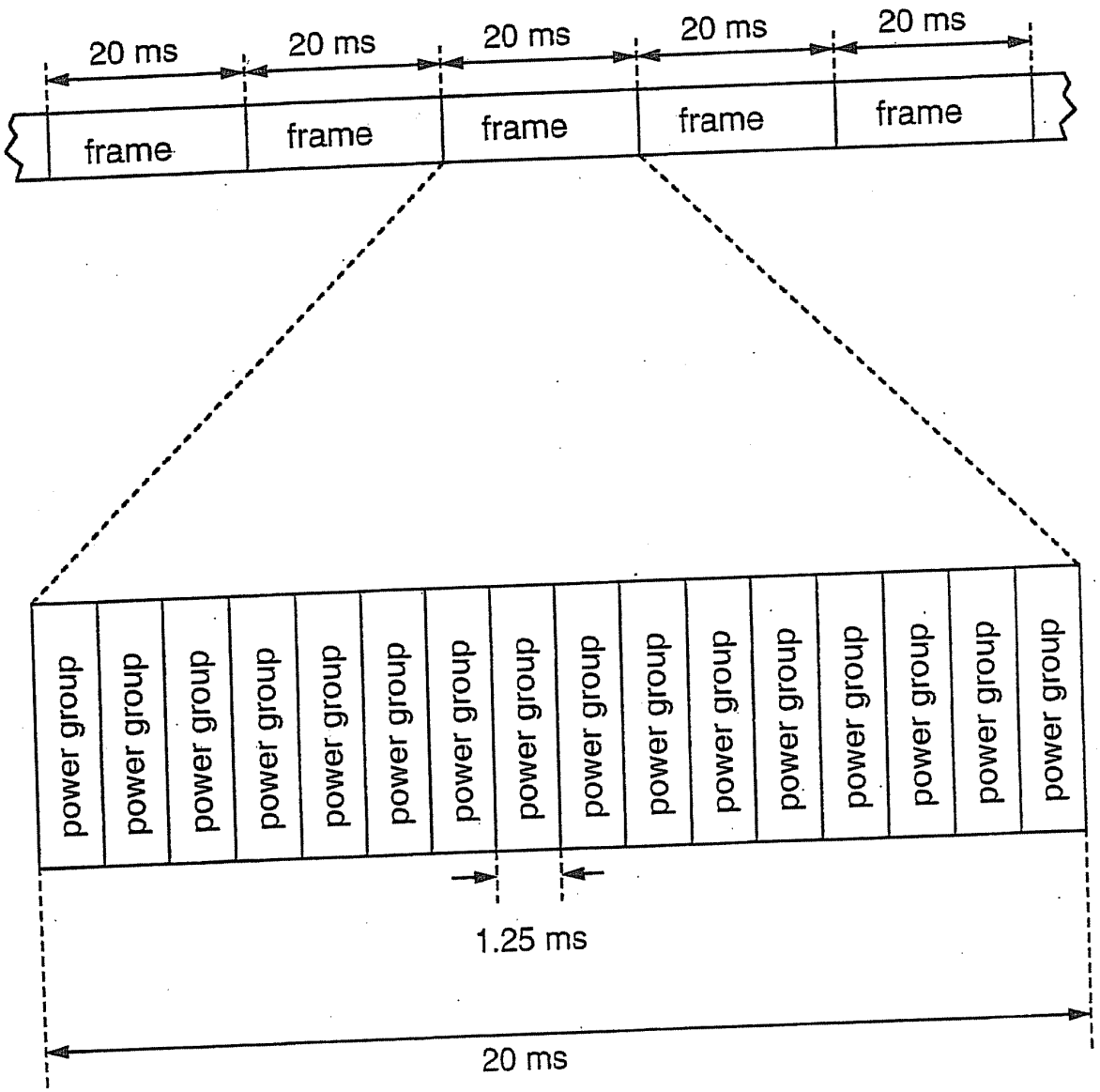

148
150
152
1 • • • p
timing and PN sequence information
COHERENT MULTICHANNEL IF DOWN CONVERTERS and A/D CONVERTERS
146
SYNCHRONIZED MULTICHANNEL DESPREADERS
154
$x_1(t)$
$x_p(t)$
$x_{1,q}(t)$
$x_{1,1}(t)$
$x_{p,q}(t)$
$x_{p,1}(t)$
144
156
SEARCHER
160
$\tau^{(1)}, \ldots, \tau^{(q)}$
$c^{(1)}, \ldots, c^{(p)}$
$x^{(1)}$ • • • $x^{(q)}$
SIGNAL PROCESSOR
158
162
location information

FIG. 4

5/13

FIG. 5


20 ms
20 ms
20 ms
20 ms
20 ms
frame
frame
frame
frame
frame
power group
1.25 ms
20 ms

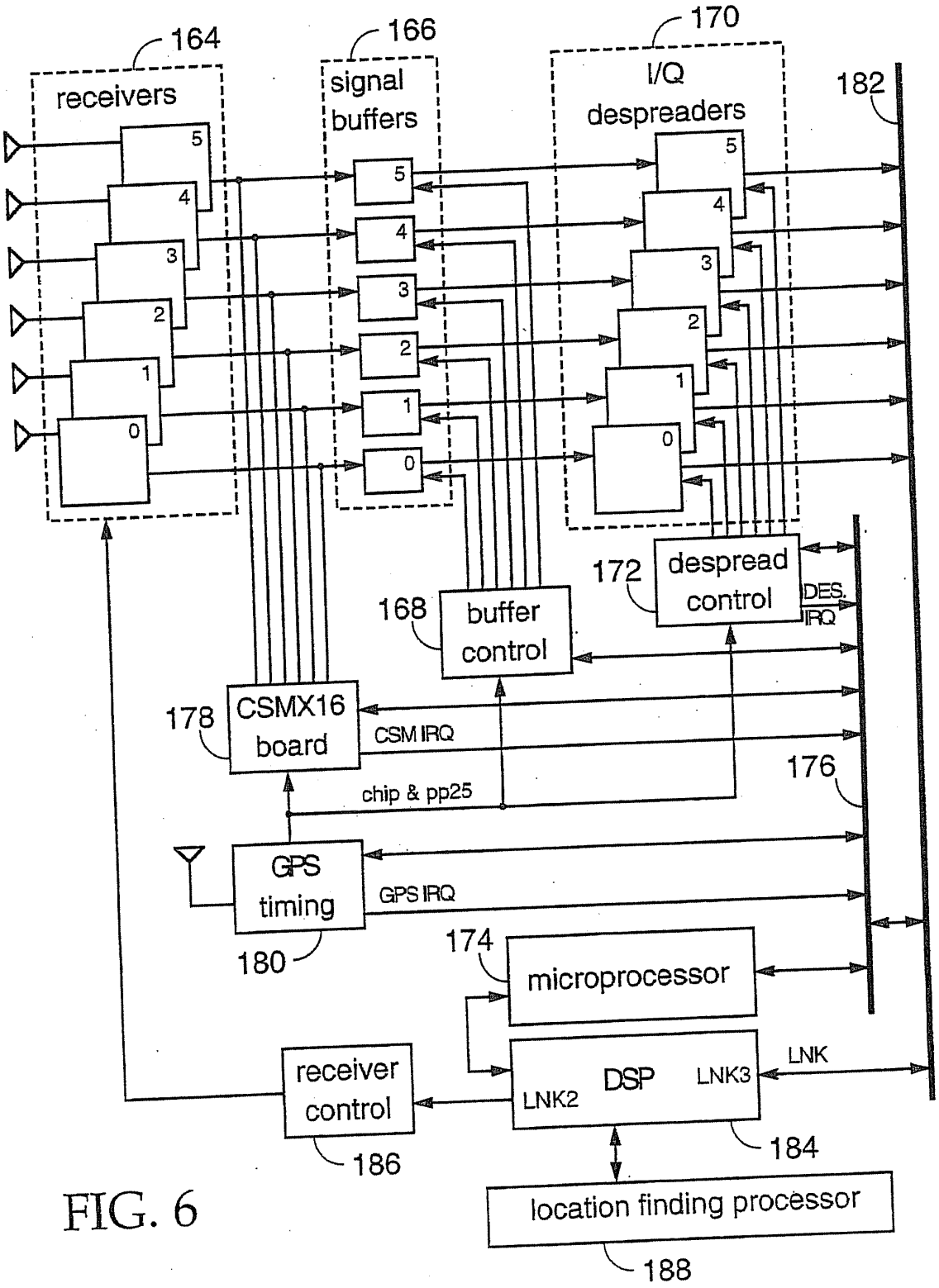

164
receivers
166
signal buffers
170
I/Q despreaders
182
5
4
3
2
1
0
172
despread control
DES. IRQ
168
buffer control
178
CSMX16 board
CSM IRQ
chip & pp25
176
GPS timing
GPS IRQ
180
174
microprocessor
receiver control
LNK2
DSP
LNK3
LNK
186
184
location finding processor
188

FIG. 6

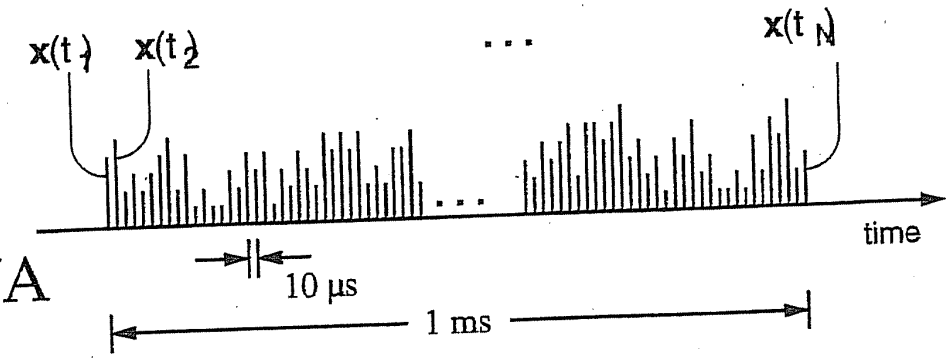


FIG. 7A

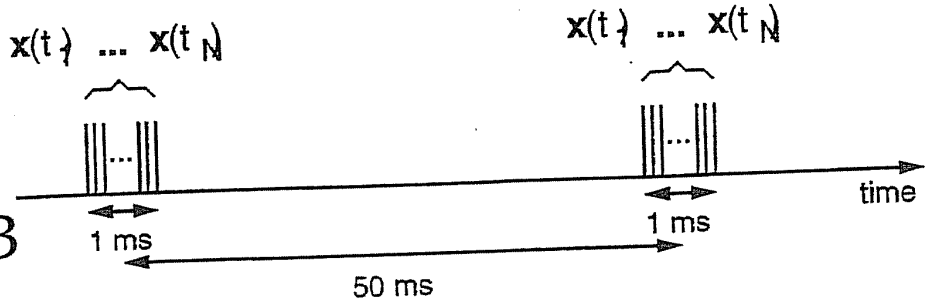


FIG. 7B

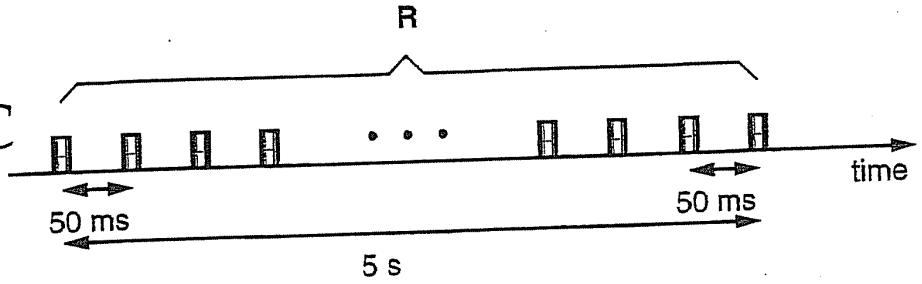


FIG. 7C

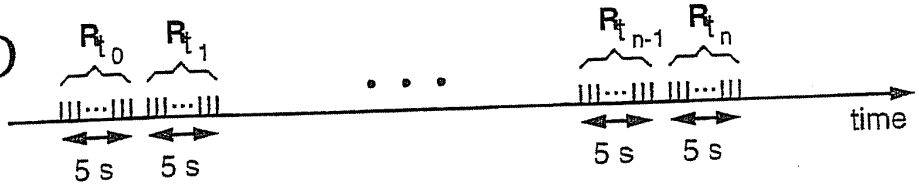


FIG. 7D

8/13

FIG. 8A

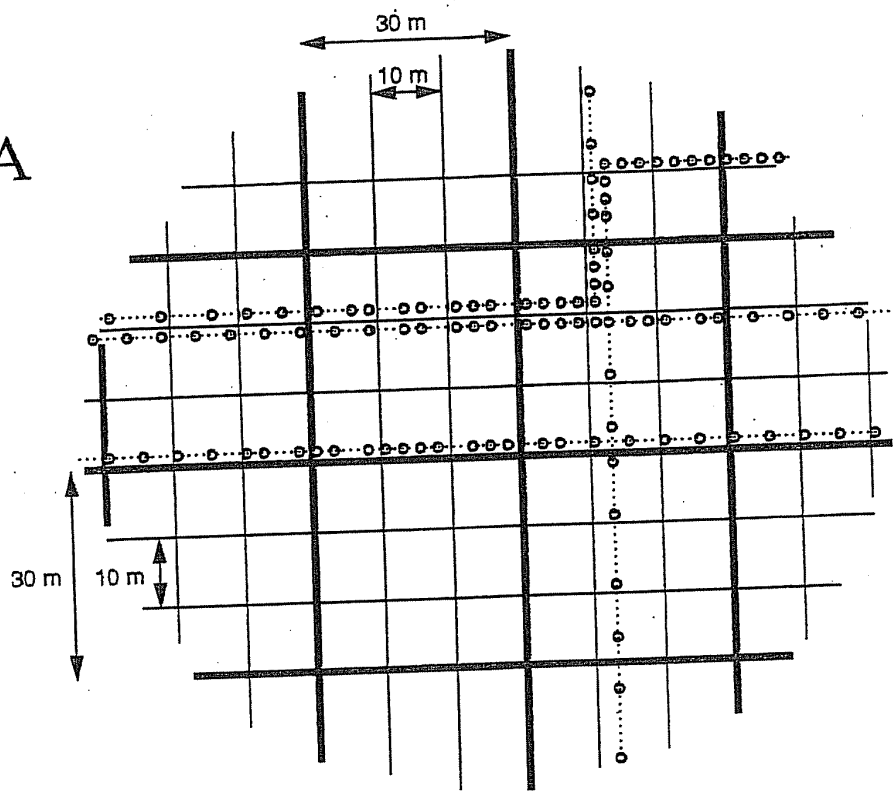
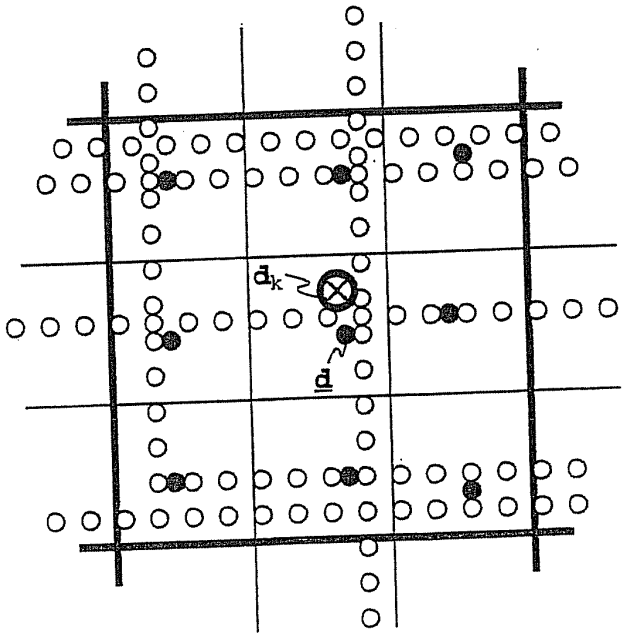


FIG. 8B



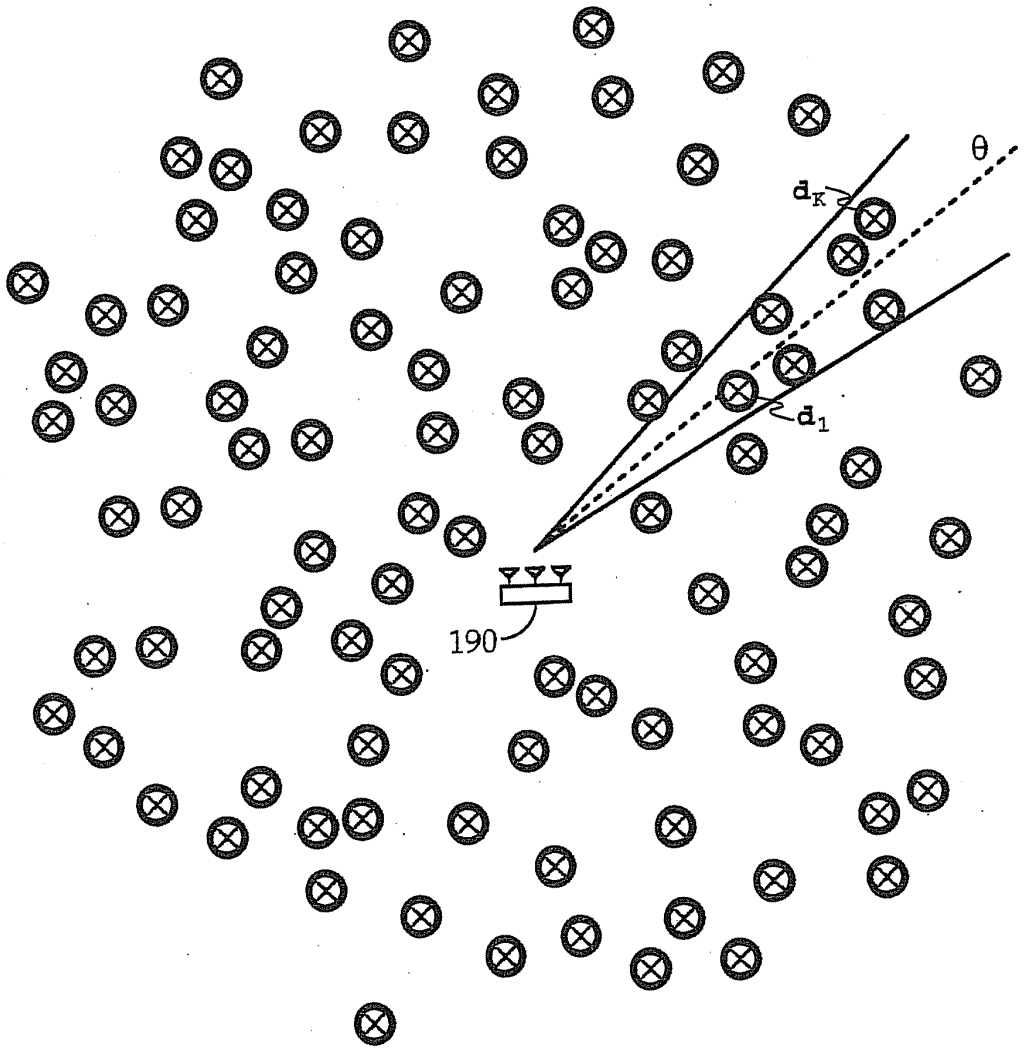


FIG. 9

FIG. 10

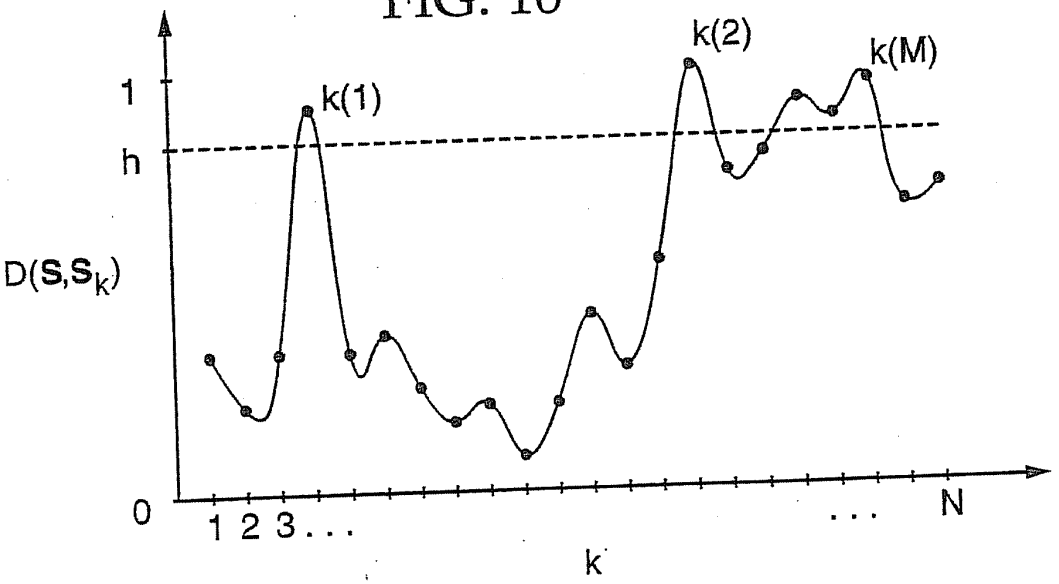
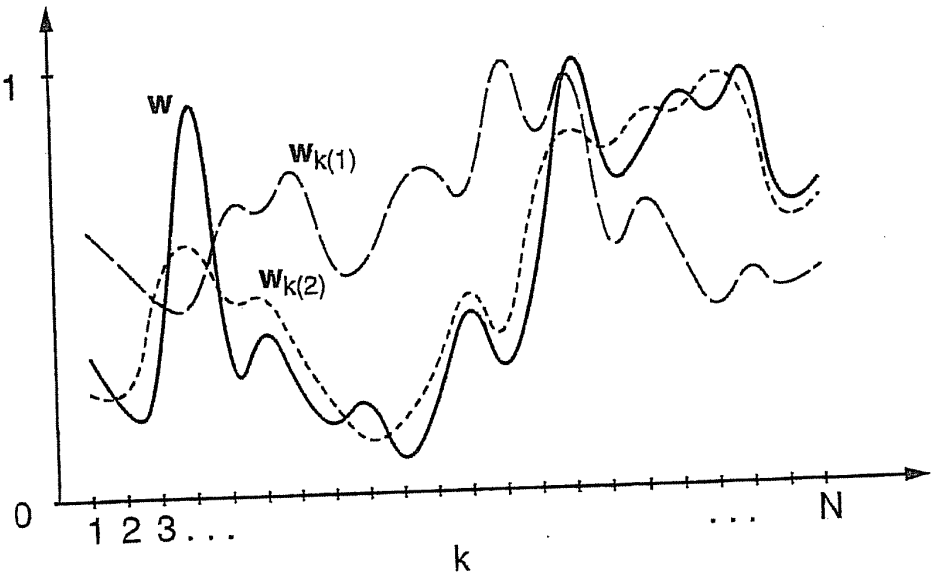


FIG. 11



11/13

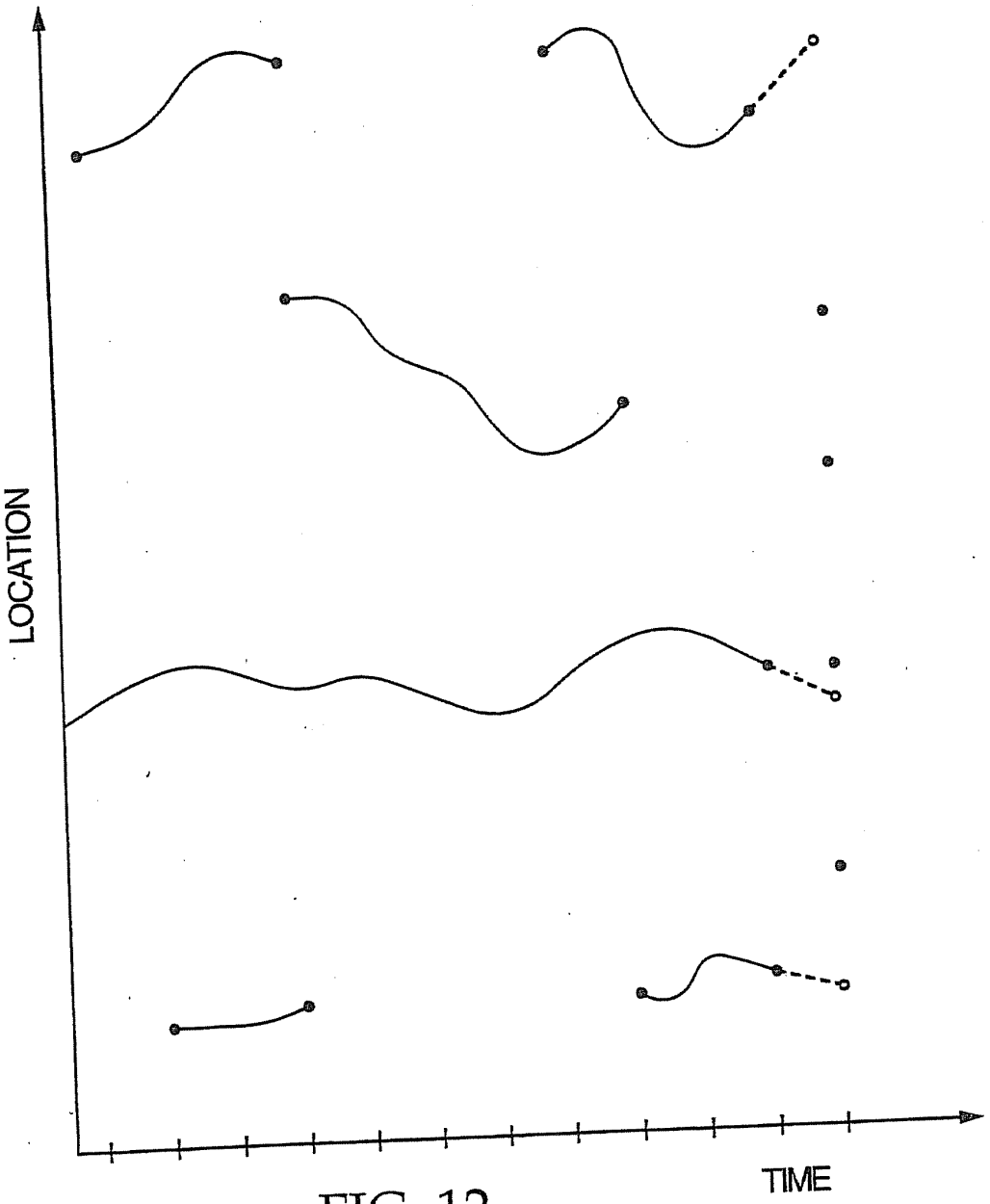


FIG. 12

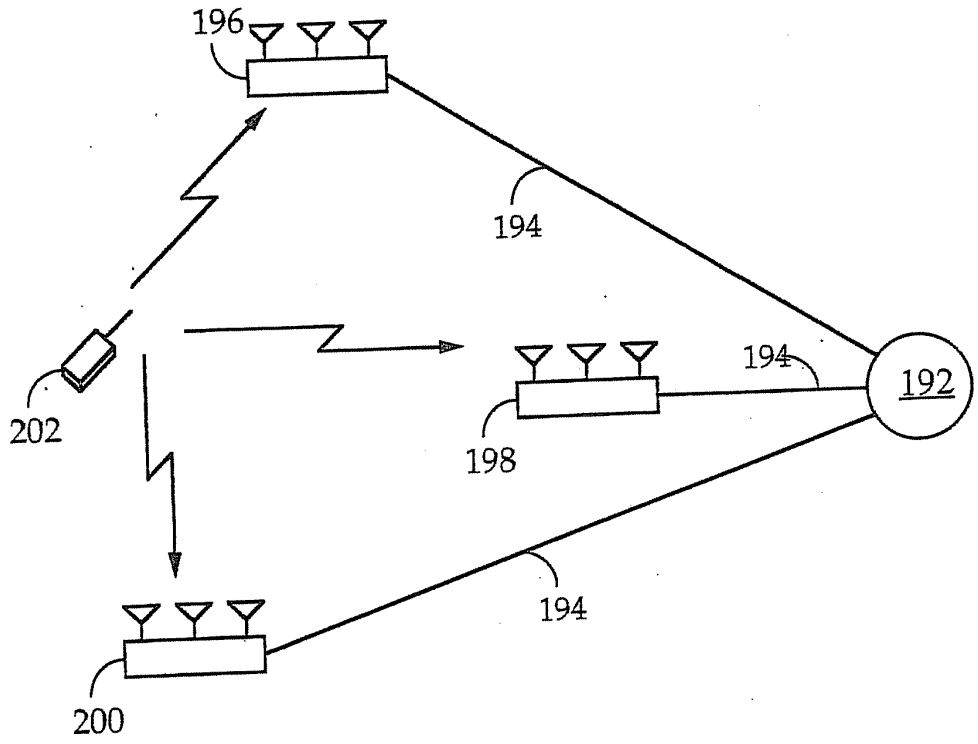


FIG. 13

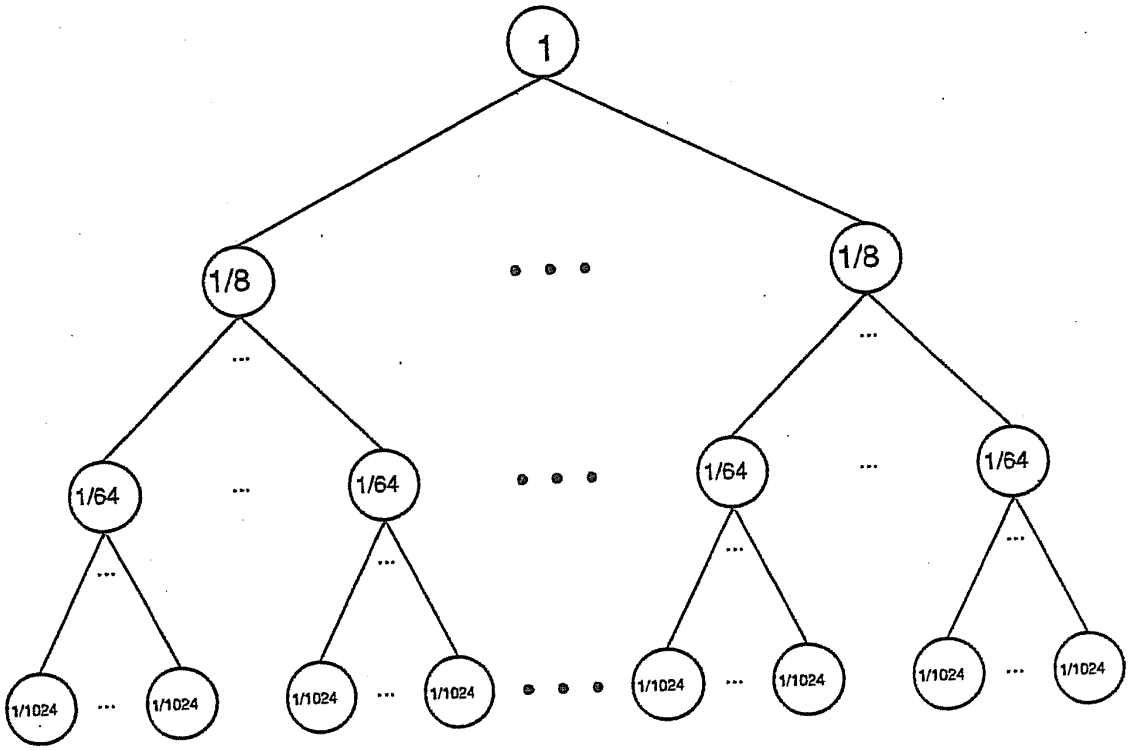

1
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1/64
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1/1024

FIG. 14

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US99/24493

A. CLASSIFICATION OF SUBJECT MATTER

IPC(7) : G01S 3/02
US CL : 342/457

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)

U.S. : 342/457, 450, 451, 453; 455/456

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)

Please See Extra Sheet.

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5,717,406 A (SANDERFORD ET AL) 10 FEBRUARY 1998 (10/02/98) IN ITS ENTIRETY	1-24
X	US 5,394,158 A (CHIA) 28 FEBRUARY 1995 (28/02/95) IN ITS ENTIRETY	1-24
X	HASHEMI, Homayoun. "Pulse Ranging Radiolocation Technique and its Application to Channel Assignment in Digital Cellular Radio", 41st IEEE Vehicular Technology Conference, 1991, 675-680.	1-24
A	JENG, S.S. et al. "Measurements of Spatial Signature of an Antenna Array", 6th Int'l Symposium Personal Indoor and Mobile Radio communications. 1995. pp. 669-672	1-24

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

*	Special categories of cited documents:	"T"	later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"A"	document defining the general state of the art which is not considered to be of particular relevance	"X"	document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"E"	earlier document published on or after the international filing date	"Y"	document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"L"	document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"&"	document member of the same patent family
"O"	document referring to an oral disclosure, use, exhibition or other means		
"P"	document published prior to the international filing date but later than the priority date claimed		

Date of the actual completion of the international search 08 MARCH 2000	Date of mailing of the international search report 10 MAY 2000
Name and mailing address of the ISA/US Commissioner of Patents and Trademarks	Authorized officer GREGORY C. ISSING

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US99/24493

B. FIELDS SEARCHED
Electronic data bases consulted (Name of data base and where practicable terms used):

IEEE DATABASE
SEARCH TERMS:(MULTIPATH, SIGNAL SIGNATURE, FINGERPRINT) AND (GEOLOCATION, LOCATION, POSITION) AND (CELLULAR,MOBILE)
BRS
SEARCH TERMS:SIMILAR TO ABOVE

Electronic Acknowledgement Receipt	
EFS ID:	4004786
Application Number:	12026480
International Application Number:	
Confirmation Number:	3162
Title of Invention:	SYSTEM AND METHOD FOR GENERATING A LOCATION ESTIMATE USING UNIFORM AND NON-UNIFORM GRID POINTS
First Named Inventor/Applicant Name:	Martin Alles
Customer Number:	79172
Filer:	Mark Charles Comtois/Jacquetta McBee
Filer Authorized By:	Mark Charles Comtois
Attorney Docket Number:	AND01 080
Receipt Date:	25-SEP-2008
Filing Date:	05-FEB-2008
Time Stamp:	14:23:55
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	no

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Information Disclosure Statement (IDS) Filed (SB/08)	AND01_080_IDS.pdf	8974990 563902e8f529e8baa91db8aba681b2b71bf604f3	no	78
Warnings:					
Information:					

This is not an USPTO supplied IDS fillable form	
Total Files Size (in bytes):	8974990

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If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.

National Stage of an International Application under 35 U.S.C. 371
If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.

New International Application Filed with the USPTO as a Receiving Office
If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

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APPLICATION NUMBER	FILING OR 371(C) DATE	FIRST NAMED APPLICANT	ATTY. DOCKET NO./TITLE
12/026,480	02/05/2008	Martin Alles	AND01 080

CONFIRMATION NO. 3162

79172
Duane Morris LLP
505 9th Street, N.W.
Suite 1000
Washington, DC 20004

PUBLICATION NOTICE

OC000000031435324

Title:SYSTEM AND METHOD FOR GENERATING A LOCATION ESTIMATE USING UNIFORM AND NON-UNIFORM GRID POINTS

Publication No.US-2008-0188237-A1
Publication Date:08/07/2008

NOTICE OF PUBLICATION OF APPLICATION

The above-identified application will be electronically published as a patent application publication pursuant to 37 CFR 1.211, et seq. The patent application publication number and publication date are set forth above.

The publication may be accessed through the USPTO's publically available Searchable Databases via the Internet at www.uspto.gov. The direct link to access the publication is currently http://www.uspto.gov/patft/.

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In addition, information on the status of the application, including the mailing date of Office actions and the dates of receipt of correspondence filed in the Office, may also be accessed via the Internet through the Patent Electronic Business Center at www.uspto.gov using the public side of the Patent Application Information and Retrieval (PAIR) system. The direct link to access this status information is currently http://pair.uspto.gov/. Prior to publication, such status information is confidential and may only be obtained by applicant using the private side of PAIR.

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Office of Data Managment, Application Assistance Unit (571) 272-4000, or (571) 272-4200, or 1-888-786-0101

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Alexandria, Virginia 22313-1450
www.uspto.gov

APPLICATION NUMBER	PATENT NUMBER	GROUP ART UNIT	FILE WRAPPER LOCATION
12/026,480		2617	

Correspondence Address / Fee Address Change

The following fields have been set to Customer Number 79172 on 06/11/2008

- Correspondence Address

The address of record for Customer Number 79172 is:
Duane Morris LLP
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Washington,DC 20004

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APPLICATION NUMBER	FILING or 371(c) DATE	GRP ART UNIT	FIL FEE REC'D	ATTY.DOCKET.NO	TOT CLAIMS	IND CLAIMS
12/026,480	02/05/2008	2617	3270	AND01 080	57	2

CONFIRMATION NO. 3162

CORRECTED FILING RECEIPT

39290
DUANE MORRIS LLP
505 9th Street
Suite 1000
WASHINGTON, DC 20004-2166



Date Mailed: 04/28/2008

Receipt is acknowledged of this non-provisional patent application. The application will be taken up for examination in due course. Applicant will be notified as to the results of the examination. Any correspondence concerning the application must include the following identification information: the U.S. APPLICATION NUMBER, FILING DATE, NAME OF APPLICANT, and TITLE OF INVENTION. Fees transmitted by check or draft are subject to collection. Please verify the accuracy of the data presented on this receipt. **If an error is noted on this Filing Receipt, please write to the Office of Initial Patent Examination's Filing Receipt Corrections. Please provide a copy of this Filing Receipt with the changes noted thereon. If you received a "Notice to File Missing Parts" for this application, please submit any corrections to this Filing Receipt with your reply to the Notice. When the USPTO processes the reply to the Notice, the USPTO will generate another Filing Receipt incorporating the requested corrections**

Applicant(s)

Martin Alles, Vienna, VA;
John Carlson, Dulles, VA;
George Maher, Herndon, VA;
Selcuk Mazlum, Leesburg, VA;

Assignment For Published Patent Application

CommScope, Inc. of North Carolina, Hickory, NC

Power of Attorney:

Donald English--42514
Patrick McPherson--46255
Mark Comtois--46285

Domestic Priority data as claimed by applicant

This appln claims benefit of 60/899,379 02/05/2007

Foreign Applications

If Required, Foreign Filing License Granted: 02/16/2008

The country code and number of your priority application, to be used for filing abroad under the Paris Convention, is **US 12/026,480**

Projected Publication Date: 08/07/2008

Non-Publication Request: No

Early Publication Request: No

Title

SYSTEM AND METHOD FOR GENERATING A LOCATION ESTIMATE USING UNIFORM AND NON-UNIFORM GRID POINTS

Preliminary Class

455

PROTECTING YOUR INVENTION OUTSIDE THE UNITED STATES

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ATTORNEY DOCKET NO. AND01 080

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re the Patent Application of Martin ALLES, et al.

Confirmation No.: 3162

Serial No.: 12/026,480 Art Unit: 3662

Filed: February 5, 2008 Examiner: Unassigned

Title: **SYSTEM AND METHOD FOR GENERATING A LOCATION ESTIMATE USING UNIFORM AND NON-UNIFORM GRID POINTS**

TRANSMITTAL

Mail Stop Office of Initial Patent
Examination Filing Receipt Corrections
Commissioner for Patents
P.O. Box 1450
Alexandria, Virginia 22313-1450

Sir:

Attached is a marked-up copy of an Official Filing Receipt issued by the U.S. Patent Trademark Office on February 19, 2008 for the above-referenced application for which issuance of a corrected filing receipt is respectfully requested, for the following reasons:

Please make the following changes to the "Applicants" section:

"Martin Alles, Hamilton Parish, MD" should read --**Vienna, VA--;**

"Selcuk Mazlum, Frederick, MD" should read --**Leesburg, VA**--.

Changes to the "Assignment for Published Patent Application" section:

"Andrew Corporation, Westchester, IL" should read--**CommScope, Inc. of North Carolina, Hickory, NC--**".

If a Petition for an Extension of Time is necessary for the paper transmitted herewith to be timely filed, this transmittal is to be considered as a petition to extend the response period by the amount of time needed for the paper to be timely filed.

The Commissioner is hereby authorized to charge payment of any additional fees associated with this communication or credit any overpayment to Deposit Account No. 04-1679.

Respectfully submitted,

/mcc/
Mark C. Comtois
Reg. No. 46,285

DUANE MORRIS LLP
505 9th Street, N.W., Suite 1000
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Telephone: (202) 776-7800
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Dated: 24 April 2008

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APPLICATION NUMBER	FILING or 371(c) DATE	GRP ART UNIT	FIL FEE REC'D	ATTY.DOCKET.NO	TOT CLAIMS	IND CLAIMS
12/026,480	02/05/2008	3662	3140	AND01 080	57	2

CONFIRMATION NO. 3162

FILING RECEIPT

39290
DUANE MORRIS LLP
505 9th Street
Suite 1000
WASHINGTON, DC 20004-2166

RECEIVED
DUANE MORRIS, LLP
FEB 21 2008

Date Mailed: 02/19/2008

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Applicant(s)

Martin Alles, ~~Hamilton Parish, MD~~; Vienna, VA
John Carlson, Dulles, VA;
George Maher, Herndon, VA;
Selcuk Mazlum, ~~Frederick, MD;~~ - Leesburg, VA

Assignment For Published Patent Application

~~Andrew Corporation, Westchester, IL~~ CommScope, Inc. of North Carolina, Hickory, NC

Power of Attorney: None

Domestic Priority data as claimed by applicant

This appln claims benefit of 60/899,379 02/05/2007

Foreign Applications

If Required, Foreign Filing License Granted: 02/16/2008

The country code and number of your priority application, to be used for filing abroad under the Paris Convention, is **US 12/026,480**

Projected Publication Date: To Be Determined - pending completion of Missing Parts

Non-Publication Request: No

Early Publication Request: No

DOCKETED

Title

SYSTEM AND METHOD FOR GENERATING A LOCATION ESTIMATE USING UNIFORM AND NON-UNIFORM GRID POINTS

Preliminary Class

342

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SUPPLEMENTAL APPLICATION DATA SHEET

Application Information

Application No.::	12/026,480
Filing Date::	02/05/2008
Application Type::	UTILITY
Title Line One::	SYSTEM AND METHOD FOR GENERATING A LOCATION ESTIMATE USING UNIFORM AND NON-UNIFORM GRID POINTS
Total Drawing Sheets::	72
Formal Drawings?::	YES
Docket Number::	AND01 080
Secrecy Order in Parent Appl?::	NO
Small Entity:	NO

Applicant Information

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Name Suffix::	
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State or Province::	Virginia
Country::	~~Bermuda~~ US
Postal or Zip Code	~~FL047~~ 22180
Citizenship Country::	US

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Name Suffix::	
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Citizenship Country::	US

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Name Suffix::	
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Citizenship Country::	US

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Citizenship Country::	~~US~~ TR

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Customer Number::	39290 Mark C. Comtois DUANE MORRIS LLP 505 9th Street, N.W. Suite 1000 Washington, D.C. 20004 Tel: 202.778.7800 Fax: 202.778.7801

Representative Information

Customer Number:: 39290

ASSIGNEE INFORMATION

Assignee name:: ~~Andrew Corporation~~ CommScope, Inc. of North Carolina
Street of mailing address:: ~~1025 West NASA Boulevard~~ 1100 CommScope Place SE
City of mailing address:: ~~Melbourne~~ Hickory, North Carolina 28602

Electronic Acknowledgement Receipt

EFS ID:	3201371
Application Number:	12026480
International Application Number:	
Confirmation Number:	3162
Title of Invention:	SYSTEM AND METHOD FOR GENERATING A LOCATION ESTIMATE USING UNIFORM AND NON-UNIFORM GRID POINTS
First Named Inventor/Applicant Name:	Martin Alles
Customer Number:	39290
Filer:	Mark Charles Comtois/Jacquetta McBee
Filer Authorized By:	Mark Charles Comtois
Attorney Docket Number:	AND01 080
Receipt Date:	24-APR-2008
Filing Date:	05-FEB-2008
Time Stamp:	11:51:29
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	no

File Listing:

Document Number	Document Description	File Name	File Size(Bytes) /Message Digest	Multi Part /.zip	Pages (if appl.)
1	Request for Corrected Filing Receipt	AND01_080_CorrectedFiliingReceipt.pdf	514358 89ff721a916ba0016e2ac4da4927c72a857aa413	no	5

Warnings:	
Information:	

2	Oath or Declaration filed	AND01_080_SupplementalADS.pdf	181215 66ae25619a408eaa54bb033bf190339b58cae28c	no	3

Warnings:	
Information:	
Total Files Size (in bytes):	695573

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12/026,480	02/05/2008	3662	3270	AND01 080	57	2

CONFIRMATION NO. 3162

UPDATED FILING RECEIPT

39290
DUANE MORRIS LLP
505 9th Street
Suite 1000
WASHINGTON, DC 20004-2166

OC000000029374109

Date Mailed: 04/14/2008

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APPLICATION NUMBER	FILING OR 371(C) DATE	FIRST NAMED APPLICANT	ATTY. DOCKET NO./TITLE
12/026,480	02/05/2008	Martin Alles	AND01 080

CONFIRMATION NO. 3162

39290
DUANE MORRIS LLP
505 9th Street
Suite 1000
WASHINGTON, DC 20004-2166

NOTICE

OC000000029374110

Date Mailed: 04/14/2008

NOTICE OF INFORMAL APPLICATION

This application is considered to be informal since it does not comply with the regulations for the reason(s) indicated below. The period within to correct the informalities noted below and avoid abandonment is set in the accompanying Office action.

Items Required To Avoid Processing Delays:

The item(s) indicated below are also required and should be submitted with any reply to this notice to avoid further processing delays.

A new oath or declaration, identifying this application number, or, if appropriate, an application data sheet (37 CFR 1.76), is required. The oath or declaration does not comply with 37 CFR 1.63 in that it:

- does not identify the residence (e.g., city and either state or foreign country) of each inventor.

UNITED STATES PATENT AND TRADEMARK OFFICE

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United States Patent and Trademark Office
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Alexandria, Virginia 22313-1450
www.uspto.gov

APPLICATION NUMBER	FILING or 371(c) DATE	GRP ART UNIT	FIL FEE REC'D	ATTY.DOCKET.NO	TOT CLAIMS	IND CLAIMS
12/026,480	02/05/2008	3662	3270	AND01 080	57	2

CONFIRMATION NO. 3162

UPDATED FILING RECEIPT

39290
DUANE MORRIS LLP
505 9th Street
Suite 1000
WASHINGTON, DC 20004-2166



Date Mailed: 04/14/2008

Receipt is acknowledged of this non-provisional patent application. The application will be taken up for examination in due course. Applicant will be notified as to the results of the examination. Any correspondence concerning the application must include the following identification information: the U.S. APPLICATION NUMBER, FILING DATE, NAME OF APPLICANT, and TITLE OF INVENTION. Fees transmitted by check or draft are subject to collection. Please verify the accuracy of the data presented on this receipt. **If an error is noted on this Filing Receipt, please write to the Office of Initial Patent Examination's Filing Receipt Corrections. Please provide a copy of this Filing Receipt with the changes noted thereon. If you received a "Notice to File Missing Parts" for this application, please submit any corrections to this Filing Receipt with your reply to the Notice. When the USPTO processes the reply to the Notice, the USPTO will generate another Filing Receipt incorporating the requested corrections**

Applicant(s)

Martin Alles, Vienna, VA;
John Carlson, Dulles, VA;
George Maher, Herndon, VA;
Selcuk Mazlum, Leesburg, VA;

Assignment For Published Patent Application

Andrew Corporation, Westchester, IL

Power of Attorney:

Donald English--42514
Patrick McPherson--46255
Mark Comtois--46285

Domestic Priority data as claimed by applicant

This appln claims benefit of 60/899,379 02/05/2007

Foreign Applications

If Required, Foreign Filing License Granted: 02/16/2008

The country code and number of your priority application, to be used for filing abroad under the Paris Convention, is **US 12/026,480**

Projected Publication Date: 08/07/2008

Non-Publication Request: No

Early Publication Request: No

Title

SYSTEM AND METHOD FOR GENERATING A LOCATION ESTIMATE USING UNIFORM AND NON-UNIFORM GRID POINTS

Preliminary Class

342

PROTECTING YOUR INVENTION OUTSIDE THE UNITED STATES

Since the rights granted by a U.S. patent extend only throughout the territory of the United States and have no effect in a foreign country, an inventor who wishes patent protection in another country must apply for a patent in a specific country or in regional patent offices. Applicants may wish to consider the filing of an international application under the Patent Cooperation Treaty (PCT). An international (PCT) application generally has the same effect as a regular national patent application in each PCT-member country. The PCT process **simplifies** the filing of patent applications on the same invention in member countries, but **does not result** in a grant of "an international patent" and does not eliminate the need of applicants to file additional documents and fees in countries where patent protection is desired.

Almost every country has its own patent law, and a person desiring a patent in a particular country must make an application for patent in that country in accordance with its particular laws. Since the laws of many countries differ in various respects from the patent law of the United States, applicants are advised to seek guidance from specific foreign countries to ensure that patent rights are not lost prematurely.

Applicants also are advised that in the case of inventions made in the United States, the Director of the USPTO must issue a license before applicants can apply for a patent in a foreign country. The filing of a U.S. patent application serves as a request for a foreign filing license. The application's filing receipt contains further information and guidance as to the status of applicant's license for foreign filing.

Applicants may wish to consult the USPTO booklet, "General Information Concerning Patents" (specifically, the section entitled "Treaties and Foreign Patents") for more information on timeframes and deadlines for filing foreign patent applications. The guide is available either by contacting the USPTO Contact Center at 800-786-9199, or it can be viewed on the USPTO website at http://www.uspto.gov/web/offices/pac/doc/general/index.html.

For information on preventing theft of your intellectual property (patents, trademarks and copyrights), you may wish to consult the U.S. Government website, http://www.stopfakes.gov. Part of a Department of Commerce initiative, this website includes self-help "toolkits" giving innovators guidance on how to protect intellectual property in specific countries such as China, Korea and Mexico. For questions regarding patent enforcement issues, applicants may call the U.S. Government hotline at 1-866-999-HALT (1-866-999-4158).

LICENSE FOR FOREIGN FILING UNDER

Title 35, United States Code, Section 184

Title 37, Code of Federal Regulations, 5.11 & 5.15

GRANTED

The applicant has been granted a license under 35 U.S.C. 184, if the phrase "IF REQUIRED, FOREIGN FILING LICENSE GRANTED" followed by a date appears on this form. Such licenses are issued in all applications where

the conditions for issuance of a license have been met, regardless of whether or not a license may be required as set forth in 37 CFR 5.15. The scope and limitations of this license are set forth in 37 CFR 5.15(a) unless an earlier license has been issued under 37 CFR 5.15(b). The license is subject to revocation upon written notification. The date indicated is the effective date of the license, unless an earlier license of similar scope has been granted under 37 CFR 5.13 or 5.14.

This license is to be retained by the licensee and may be used at any time on or after the effective date thereof unless it is revoked. This license is automatically transferred to any related applications(s) filed under 37 CFR 1.53(d). This license is not retroactive.

The grant of a license does not in any way lessen the responsibility of a licensee for the security of the subject matter as imposed by any Government contract or the provisions of existing laws relating to espionage and the national security or the export of technical data. Licensees should apprise themselves of current regulations especially with respect to certain countries, of other agencies, particularly the Office of Defense Trade Controls, Department of State (with respect to Arms, Munitions and Implements of War (22 CFR 121-128)); the Bureau of Industry and Security, Department of Commerce (15 CFR parts 730-774); the Office of Foreign AssetsControl, Department of Treasury (31 CFR Parts 500+) and the Department of Energy.

NOT GRANTED

No license under 35 U.S.C. 184 has been granted at this time, if the phrase "IF REQUIRED, FOREIGN FILING LICENSE GRANTED" DOES NOT appear on this form. Applicant may still petition for a license under 37 CFR 5.12, if a license is desired before the expiration of 6 months from the filing date of the application. If 6 months has lapsed from the filing date of this application and the licensee has not received any indication of a secrecy order under 35 U.S.C. 181, the licensee may foreign file the application pursuant to 37 CFR 5.15(b).

AND01 080
1485

COMBINED DECLARATION AND POWER OF ATTORNEY FOR UTILITY PATENT APPLICATION

As a below named inventor, I hereby declare:

that my residence, post office address and citizenship are as stated below next to my name;

that I verily believe that I am the original, first and sole inventor (if only one name is listed below) or a joint inventor (if plural inventors are named below) of the invention which is the subject of an application entitled: SYSTEM AND METHOD FOR GENERATING A LOCATION ESTIMATE USING UNIFORM AND NON-UNIFORM GRID POINTS; said invention being described and claimed [ ] in the attached specification [X] in the specification of application Serial No. 12/026,480 filed February 5, 2008; that I have reviewed and understand the content of said specification including the claims; that I do not know and do not believe the said invention was ever known or used in the United States before my or our invention thereof, or patented or described in any printed publication in any country before my or our invention thereof or more than one year prior to said application; that said invention was not in public use or on sale in the United States more than one year prior to said application; that said invention has not been patented or made the subject of an inventor's certificate issued before the date of said application in any country foreign to the United States on an application filed by me or my legal representatives or assigns more than twelve months prior to said application; that I acknowledge my duty to disclose information of which I am aware which is material to patentability as defined in 37 CFR 1.56; and that no application for patent or inventor's certificate on this invention has been filed in any country foreign to the United States prior to said application by me or my legal representatives or assigns, except as follows:

COUNTRY/INTERNATIONAL	APPLICATION NUMBER	DATE OF FILING (day, month, year)	PRIORITY CLAIMED UNDER 35 U.S.C. 119/36
			YES___ NO__
			YES___ NO__

I hereby claim the benefit under 35 U.S.C. § 119(e) of any United States provisional application listed below:

60/899,379, filed on 05 February 2007

I hereby appoint Mark C. Comtois, Reg. No. 46,285; Joseph English, Reg. No. 42,514; Patrick D. McPherson, Reg. No. 46,255 to prosecute said application and to transact all business in the Patent and Trademark Office connected therewith and to file, prosecute and transact all business in connection with international applications directed to said invention:

Address all correspondence to: Duane Morris LLP
505 9th Street, N.W., Suite 1000
Washington, DC 20004

Direct all telephone calls to (202) 776-7800

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

Martin ALLES — X [signature] — 03/14/08
FULL NAME OF INVENTOR — SIGNATURE — DATE

2421 Williams Avenue
~~BM~~ US

Vienna, VA 22180
POST OFFICE ADDRESS

John CARLSON — X [signature] — 3/13/08
FULL NAME OF INVENTOR — SIGNATURE — DATE

DM2\1370544.1

43479 Ogden Place
RESIDENCE

US
CITIZENSHIP

Dulles, Virginia 20166
POST OFFICE ADDRESS

George MAHER
FULL NAME OF INVENTOR

X George C Maher 3/12/2008
SIGNATURE DATE

100 Adele Garden Way
RESIDENCE

US
CITIZENSHIP

Herndon, Virginia 20170
POST OFFICE ADDRESS

Selcuk MAZLUM
FULL NAME OF INVENTOR

X S Mazlum 3/12/2008
SIGNATURE DATE

136 Clubhouse Drive SW, Apt. 201
RESIDENCE

Turkey
CITIZENSHIP

Leesburg, Virginia 20175
POST OFFICE ADDRESS

DM2\1370544.1

Electronic Patent Application Fee Transmittal

Application Number:	12026480
Filing Date:	05-Feb-2008
Title of Invention:	SYSTEM AND METHOD FOR GENERATING A LOCATION ESTIMATE USING UNIFORM AND NON-UNIFORM GRID POINTS
First Named Inventor/Applicant Name:	Martin Alles
Filer:	Mark Charles Comtois/Jacquetta McBee
Attorney Docket Number:	AND01 080
Filed as Large Entity	

Utility Filing Fees

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Basic Filing:				
Pages:				
Claims:				
Miscellaneous-Filing:				
Late filing fee for oath or declaration	1051	1	130	130
Petition:				
Patent-Appeals-and-Interference:				
Post-Allowance-and-Post-Issuance:				
Extension-of-Time:				

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Miscellaneous:				
			Total in USD ($)	**130**

Electronic Acknowledgement Receipt	
EFS ID:	3086468
Application Number:	12026480
International Application Number:	
Confirmation Number:	3162
Title of Invention:	SYSTEM AND METHOD FOR GENERATING A LOCATION ESTIMATE USING UNIFORM AND NON-UNIFORM GRID POINTS
First Named Inventor/Applicant Name:	Martin Alles
Customer Number:	39290
Filer:	Mark Charles Comtois/Jacquetta McBee
Filer Authorized By:	Mark Charles Comtois
Attorney Docket Number:	AND01 080
Receipt Date:	01-APR-2008
Filing Date:	05-FEB-2008
Time Stamp:	15:39:20
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	yes
Payment Type	Deposit Account
Payment was successfully received in RAM	$130
RAM confirmation Number	942
Deposit Account	041679
Authorized User	
The Director of the USPTO is hereby authorized to charge indicated fees and credit any overpayment as follows: Charge any Additional Fees required under 37 C.F.R. Section 1.21 (Miscellaneous fees and charges)	

File Listing:

Document Number	Document Description	File Name	File Size(Bytes) /Message Digest	Multi Part /.zip	Pages (if appl.)
1	Oath or Declaration filed	AND01_080_Declaration.pdf	180467 1221df351905e449a46ea5fd2b45b6a8e9ceb411	no	2
Warnings:					
Information:					
2	Fee Worksheet (PTO-06)	fee-info.pdf	8211 fc13420ab8d1518d9197613927fd212913ab3b44	no	2
Warnings:					
Information:					
		Total Files Size (in bytes):	188678		

This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503.

New Applications Under 35 U.S.C. 111
If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.

National Stage of an International Application under 35 U.S.C. 371
If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.

New International Application Filed with the USPTO as a Receiving Office
If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

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APPLICATION NUMBER	FILING or 371(c) DATE	GRP ART UNIT	FIL FEE REC'D	ATTY.DOCKET.NO	TOT CLAIMS	IND CLAIMS
12/026,480	02/05/2008	3662	3140	AND01 080	57	2

CONFIRMATION NO. 3162

39290
DUANE MORRIS LLP
505 9th Street
Suite 1000
WASHINGTON, DC 20004-2166

FILING RECEIPT



Date Mailed: 02/19/2008

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Applicant(s)

Martin Alles, Hamilton Parish, MD;
John Carlson, Dulles, VA;
George Maher, Herndon, VA;
Selcuk Mazlum, Frederick, MD;

Assignment For Published Patent Application

Andrew Corporation, Westchester, IL

Power of Attorney: None

Domestic Priority data as claimed by applicant

This appln claims benefit of 60/899,379 02/05/2007

Foreign Applications

If Required, Foreign Filing License Granted: 02/16/2008

The country code and number of your priority application, to be used for filing abroad under the Paris Convention, is **US 12/026,480**

Projected Publication Date: To Be Determined - pending completion of Missing Parts

Non-Publication Request: No

Early Publication Request: No

Title

SYSTEM AND METHOD FOR GENERATING A LOCATION ESTIMATE USING UNIFORM AND NON-UNIFORM GRID POINTS

Preliminary Class

342

PROTECTING YOUR INVENTION OUTSIDE THE UNITED STATES

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LICENSE FOR FOREIGN FILING UNDER

Title 35, United States Code, Section 184

Title 37, Code of Federal Regulations, 5.11 & 5.15

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NOT GRANTED

No license under 35 U.S.C. 184 has been granted at this time, if the phrase "IF REQUIRED, FOREIGN FILING LICENSE GRANTED" DOES NOT appear on this form. Applicant may still petition for a license under 37 CFR 5.12, if a license is desired before the expiration of 6 months from the filing date of the application. If 6 months has lapsed from the filing date of this application and the licensee has not received any indication of a secrecy order under 35 U.S.C. 181, the licensee may foreign file the application pursuant to 37 CFR 5.15(b).

UNITED STATES PATENT AND TRADEMARK OFFICE

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APPLICATION NUMBER	FILING OR 371(C) DATE	FIRST NAMED APPLICANT	ATTY. DOCKET NO./TITLE
12/026,480	02/05/2008	Martin Alles	AND01 080

CONFIRMATION NO. 3162

39290
DUANE MORRIS LLP
505 9th Street
Suite 1000
WASHINGTON, DC 20004-2166

FORMALITIES LETTER

OC000000028357206

Date Mailed: 02/19/2008

NOTICE TO FILE MISSING PARTS OF NONPROVISIONAL APPLICATION

FILED UNDER 37 CFR 1.53(b)

Filing Date Granted

Items Required To Avoid Abandonment:

An application number and filing date have been accorded to this application. The item(s) indicated below, however, are missing. Applicant is given **TWO MONTHS** from the date of this Notice within which to file all required items and pay any fees required below to avoid abandonment. Extensions of time may be obtained by filing a petition accompanied by the extension fee under the provisions of 37 CFR 1.136(a).

- The oath or declaration is missing.
  A properly signed oath or declaration in compliance with 37 CFR 1.63, identifying the application by the above Application Number and Filing Date, is required.
  Note: If a petition under 37 CFR 1.47 is being filed, an oath or declaration in compliance with 37 CFR 1.63 signed by all available joint inventors, or if no inventor is available by a party with sufficient proprietary interest, is required.

The applicant needs to satisfy supplemental fees problems indicated below.

The required item(s) identified below must be timely submitted to avoid abandonment:

- To avoid abandonment, a surcharge (for late submission of filing fee, search fee, examination fee or oath or declaration) as set forth in 37 CFR 1.16(f) of $**130** for a non-small entity, must be submitted with the missing items identified in this notice.

SUMMARY OF FEES DUE:

Total additional fee(s) required for this application is $**130** for a non-small entity
- $**130** Surcharge.

Replies should be mailed to:

Mail Stop Missing Parts
Commissioner for Patents
P.O. Box 1450
Alexandria VA 22313-1450

Registered users of EFS-Web may alternatively submit their reply to this notice via EFS-Web.
https://sportal.uspto.gov/authenticate/AuthenticateUserLocalEPF.html

For more information about EFS-Web please call the USPTO Electronic Business Center at **1-866-217-9197** or visit our website at http://www.uspto.gov/ebc.

If you are not using EFS-Web to submit your reply, you must include a copy of this notice.

/kalhaidari/

Office of Initial Patent Examination (571) 272-4000 or 1-800-PTO-9199

PTO/SB/05 (07-07)
Approved for use through 06/30/2010. OMB 0651-0032
U.S. Patent and Trademark Office. U.S. DEPARTMENT OF COMMERCE
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UTILITY PATENT APPLICATION TRANSMITTAL

(Only for new nonprovisional applications under 37 CFR 1.53(b))

Attorney Docket No.	AND01 080
First Inventor	Martin ALLES
Title	SYSTEM AND METHOD FOR GENERATIN
Express Mail Label No.	

APPLICATION ELEMENTS

See MPEP chapter 600 concerning utility patent application contents.

1. ☑ **Fee Transmittal Form** (e.g., PTO/SB/17)
   (Submit an original and a duplicate for fee processing)
2. ☐ **Applicant claims small entity status.**
   See 37 CFR 1.27.
3. ☑ **Specification** [*Total Pages* 122]
   Both the claims and abstract must start on a new page
   (For information on the preferred arrangement, see MPEP 608.01(a))
4. ☑ **Drawing(s)** (*35 U.S.C. 113*) [*Total Sheets* 72]
5. **Oath or Declaration** [*Total Sheets* _____]
   a. ☐ Newly executed (original or copy)
   b. ☐ A copy from a prior application (37 CFR 1.63(d))
   (for continuation/divisional with Box 18 completed)
   i. ☐ DELETION OF INVENTOR(S)
   Signed statement attached deleting inventor(s) name in the prior application, see 37 CFR 1.63(d)(2) and 1.33(b).
6. ☑ **Application Data Sheet.** See 37 CFR 1.76
7. ☐ **CD-ROM or CD-R** in duplicate, large table or Computer Program *(Appendix)*
   ☐ Landscape Table on CD
8. **Nucleotide and/or Amino Acid Sequence Submission**
   (if applicable, items a. – c. are required)
   a. ☐ Computer Readable Form (CRF)
   b. Specification Sequence Listing on:
      i. ☐ CD-ROM or CD-R (2 copies); or
      ii. ☐ Paper
   c. ☐ Statements verifying identity of above copies

ADDRESS TO:

Commissioner for Patents
P.O. Box 1450
Alexandria VA 22313-1450

ACCOMPANYING APPLICATION PARTS

9. ☐ **Assignment Papers** (cover sheet & document(s))
   Name of Assignee _____
10. ☐ **37 CFR 3.73(b) Statement** *(when there is an assignee)* ☐ **Power of Attorney**
11. ☐ **English Translation Document** *(if applicable)*
12. ☐ **Information Disclosure Statement** (PTO/SB/08 or PTO-1449)
    ☐ Copies of citations attached
13. ☐ **Preliminary Amendment**
14. ☐ **Return Receipt Postcard** (MPEP 503)
    (Should be specifically itemized)
15. ☐ **Certified Copy of Priority Document(s)**
    (if foreign priority is claimed)
16. ☐ **Nonpublication Request** under 35 U.S.C. 122(b)(2)(B)(i). Applicant must attach form PTO/SB/35 or equivalent.
17. ☐ Other: _____

18. If a CONTINUING APPLICATION, *check appropriate box, and supply the requisite information below and in the first sentence of the specification following the title, or in an Application Data Sheet under 37 CFR 1.76:*

☐ Continuation ☐ Divisional ☐ Continuation-in-part (CIP) of prior application No.: .....

Prior application information: *Examiner* _____ *Art Unit:* _____

19. CORRESPONDENCE ADDRESS

☑ The address associated with Customer Number: 39290 ***OR*** ☐ Correspondence address below

Name	Duane Morris LLP				
Address	505 9th Street, N.W., Suite 1000				
City	Washington	State	D.C.	Zip Code	20004-2166
Country	USA	Telephone	202.776-7800	Email	

Signature	/mcc/	Date	05 February 2008
Name (Print/Type)	Mark C. Comtois	Registration No. (Attorney/Agent)	46,285

This collection of information is required by 37 CFR 1.53(b). The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.11 and 1.14. This collection is estimated to take 12 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

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PTO/SB/17 (10-07)
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Effective on 12/08/2004.
Fees pursuant to the Consolidated Appropriations Act, 2005 (H.R. 4818).

FEE TRANSMITTAL
For FY 2008

☐ Applicant claims small entity status. See 37 CFR 1.27

TOTAL AMOUNT OF PAYMENT ($) $3,400.00

Complete if Known	
Application Number	New Application
Filing Date	05 February 2008
First Named Inventor	Martin ALLES
Examiner Name	Unassigned
Art Unit	Unassigned
Attorney Docket No.	AND01 080

METHOD OF PAYMENT (check all that apply)

☐ Check ☐ Credit Card ☐ Money Order ☐ None ☐ Other (please identify): _____

☑ Deposit Account Deposit Account Number: 04-1679 Deposit Account Name: Duane Morris LLP

For the above-identified deposit account, the Director is hereby authorized to: (check all that apply)

☑ Charge fee(s) indicated below ☐ Charge fee(s) indicated below, **except for the filing fee**

☑ Charge any additional fee(s) or underpayments of fee(s) under 37 CFR 1.16 and 1.17 ☑ Credit any overpayments

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FEE CALCULATION

1. BASIC FILING, SEARCH, AND EXAMINATION FEES

	FILING FEES		SEARCH FEES		EXAMINATION FEES		
		Small Entity		Small Entity		Small Entity	
Application Type	Fee ($)	Fee ($)	Fee ($)	Fee ($)	Fee ($)	Fee ($)	Fees Paid ($)
Utility	310	155	510	255	210	105	1,030.00
Design	210	105	100	50	130	65	
Plant	210	105	310	155	160	80	
Reissue	310	155	510	255	620	310	
Provisional	210	105	0	0	0	0	

2. EXCESS CLAIM FEES

Fee Description	Fee ($)	Small Entity Fee ($)
Each claim over 20 (including Reissues)	50	25
Each independent claim over 3 (including Reissues)	210	105
Multiple dependent claims	370	185

Total Claims		Extra Claims	Fee ($)		Fee Paid ($)
57	- 20 or HP =	37	x 50.00	=	1,850.00

HP = highest number of total claims paid for, if greater than 20.

Indep. Claims		Extra Claims	Fee ($)		Fee Paid ($)
2	- 3 or HP =	0	x 0	=	0.00

HP = highest number of independent claims paid for, if greater than 3.

Multiple Dependent Claims	
Fee ($)	Fee Paid ($)

3. APPLICATION SIZE FEE

If the specification and drawings exceed 100 sheets of paper (excluding electronically filed sequence or computer listings under 37 CFR 1.52(e)), the application size fee due is $260 ($130 for small entity) for each additional 50 sheets or fraction thereof. See 35 U.S.C. 41(a)(1)(G) and 37 CFR 1.16(s).

Total Sheets		Extra Sheets		Number of each additional 50 or fraction thereof		Fee ($)		Fee Paid ($)
194	- 100 =	93	/ 50 =	2	(round **up** to a whole number) x	260.00	=	520.00

4. OTHER FEE(S)

	Fees Paid ($)
Non-English Specification, $130 fee (no small entity discount)	
Other (e.g., late filing surcharge): _____	

SUBMITTED BY

Signature	/mcc/	Registration No. (Attorney/Agent) 46,285	Telephone 202-776-7800
Name (Print/Type)	Mark C. Comtois		Date 05 February 2008

This collection of information is required by 37 CFR 1.136. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 30 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

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Application Data Sheet 37 CFR 1.76	Attorney Docket Number	AND01 080
	Application Number	
Title of Invention	SYSTEM AND METHOD FOR GENERATING AS LOCATION ESTIMATE USIGN UNIFORM AND NON-UNIFORM GRID POINTS	

The application data sheet is part of the provisional or nonprovisional application for which it is being submitted. The following form contains the bibliographic data arranged in a format specified by the United States Patent and Trademark Office as outlined in 37 CFR 1.76.
This document may be completed electronically and submitted to the Office in electronic format using the Electronic Filing System (EFS) or the document may be printed and included in a paper filed application.

Secrecy Order 37 CFR 5.2

☐ Portions or all of the application associated with this Application Data Sheet may fall under a Secrecy Order pursuant to 37 CFR 5.2 (Paper filers only. Applications that fall under Secrecy Order may not be filed electronically.)

Applicant Information:

Applicant 1

Applicant Authority ◉ Inventor ○ Legal Representative under 35 U.S.C. 117 ○ Party of Interest under 35 U.S.C. 118

Prefix	Given Name	Middle Name	Family Name	Suffix
	Martin		ALLES	

Residence Information (Select One) ◉ US Residency ○ Non US Residency ○ Active US Military Service

City	Hamilton Parish	State/Province	MD	Country of Residence	BM

Citizenship under 37 CFR 1.41(b) BM

Mailing Address of Applicant:

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Applicant 2

Applicant Authority ◉ Inventor ○ Legal Representative under 35 U.S.C. 117 ○ Party of Interest under 35 U.S.C. 118

Prefix	Given Name	Middle Name	Family Name	Suffix
	John		CARLSON	

Residence Information (Select One) ◉ US Residency ○ Non US Residency ○ Active US Military Service

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Citizenship under 37 CFR 1.41(b) US

Mailing Address of Applicant:

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Postal Code	20166	Country	US

Applicant 3

Applicant Authority ◉ Inventor ○ Legal Representative under 35 U.S.C. 117 ○ Party of Interest under 35 U.S.C. 118

Prefix	Given Name	Middle Name	Family Name	Suffix
	George		MAHER	

Residence Information (Select One) ◉ US Residency ○ Non US Residency ○ Active US Military Service

City	Herndon	State/Province	VA	Country of Residence	US

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Application Data Sheet 37 CFR 1.76	Attorney Docket Number	AND01 080
	Application Number	
Title of Invention	SYSTEM AND METHOD FOR GENERATING AS LOCATION ESTIMATE USIGN UNIFORM AND NON-UNIFORM GRID POINTS	

Citizenship under 37 CFR 1.41(b)	US				
Mailing Address of Applicant:					
Address 1	100 Adele Garden Way				
Address 2					
City	Herndon	**State/Province**	VA		
Postal Code	20170	**Country**	US		

Applicant 4

Applicant Authority	◉ Inventor	○ Legal Representative under 35 U.S.C. 117	○ Party of Interest under 35 U.S.C. 118		
Prefix	**Given Name**	**Middle Name**	**Family Name**	**Suffix**	
	Selcuk		MAZLUM		
Residence Information (Select One)	◉ US Residency	○ Non US Residency	○ Active US Military Service		
City	Frederick	**State/Province**	MD	**Country of Residence**	US
Citizenship under 37 CFR 1.41(b)	US				
Mailing Address of Applicant:					
Address 1	7144 Canterbury Court				
Address 2					
City	Frederick	**State/Province**	MD		
Postal Code	21073	**Country**	US		

All Inventors Must Be Listed - Additional Inventor Information blocks may be generated within this form by selecting the **Add** button. Add

Correspondence Information:

Enter either Customer Number or complete the Correspondence Information section below.
For further information see 37 CFR 1.33(a).

☐ **An Address is being provided for the correspondence Information of this application.**

Customer Number	39290		
Email Address		Add Email	Remove Email

Application Information:

Title of the Invention	SYSTEM AND METHOD FOR GENERATING AS LOCATION ESTIMATE USIGN UNIFORM AND NON-UNIFORM GRID POINTS		
Attorney Docket Number	AND01 080	**Small Entity Status Claimed**	☐
Application Type	Nonprovisional		
Subject Matter	Utility		
Suggested Class (if any)		**Sub Class (if any)**	
Suggested Technology Center (if any)			
Total Number of Drawing Sheets (if any)	72	**Suggested Figure for Publication (if any)**	

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Application Data Sheet 37 CFR 1.76	Attorney Docket Number	AND01 080
	Application Number	
Title of Invention	SYSTEM AND METHOD FOR GENERATING AS LOCATION ESTIMATE USIGN UNIFORM AND NON-UNIFORM GRID POINTS	

Publication Information:

☐ Request Early Publication (Fee required at time of Request 37 CFR 1.219)
☐ **Request Not to Publish.** I hereby request that the attached application not be published under 35 U.S. C. 122(b) and certify that the invention disclosed in the attached application **has not and will not** be the subject of an application filed in another country, or under a multilateral international agreement, that requires publication at eighteen months after filing.

Representative Information:

Representative information should be provided for all practitioners having a power of attorney in the application. Providing this information in the Application Data Sheet does not constitute a power of attorney in the application (see 37 CFR 1.32).
Enter either Customer Number or complete the Representative Name section below. If both sections are completed the Customer Number will be used for the Representative Information during processing.

Please Select One:	◉ Customer Number	○ US Patent Practitioner	○ Limited Recognition (37 CFR 11.9)
Customer Number	39290		

Domestic Benefit/National Stage Information:

This section allows for the applicant to either claim benefit under 35 U.S.C. 119(e), 120, 121, or 365(c) or indicate National Stage entry from a PCT application. Providing this information in the application data sheet constitutes the specific reference required by 35 U.S.C. 119(e) or 120, and 37 CFR 1.78(a)(2) or CFR 1.78(a)(4), and need not otherwise be made part of the specification.

Prior Application Status	Expired	Remove	
Application Number	Continuity Type	Prior Application Number	Filing Date (YYYY-MM-DD)
	non provisional of	60899379	2007-02-05

Additional Domestic Benefit/National Stage Data may be generated within this form by selecting the **Add** button.

Foreign Priority Information:

This section allows for the applicant to claim benefit of foreign priority and to identify any prior foreign application for which priority is not claimed. Providing this information in the application data sheet constitutes the claim for priority as required by 35 U.S.C. 119(b) and 37 CFR 1.55(a).

		Remove	
Application Number	Country	Parent Filing Date (YYYY-MM-DD)	Priority Claimed
			◉ Yes ○ No

Additional Foreign Priority Data may be generated within this form by selecting the **Add** button.

Assignee Information:

Providing this information in the application data sheet does not substitute for compliance with any requirement of part 3 of Title 37 of the CFR to have an assignment recorded in the Office.

Assignee 1

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Application Data Sheet 37 CFR 1.76	Attorney Docket Number	AND01 080
	Application Number	
Title of Invention	SYSTEM AND METHOD FOR GENERATING AS LOCATION ESTIMATE USIGN UNIFORM AND NON-UNIFORM GRID POINTS	

If the Assignee is an Organization check here. ☒			
Organization Name	Andrew Corporation		
Mailing Address Information:			
Address 1	3 Westbrook Corporate Center		
Address 2	Suite 900		
City	Westchester	**State/Province**	IL
Country	US	Postal Code	60154
Phone Number		Fax Number	
Email Address			
Additional Assignee Data may be generated within this form by selecting the **Add** button.			

Signature:

A signature of the applicant or representative is required in accordance with 37 CFR 1.33 and 10.18. Please see 37 CFR 1.4(d) for the form of the signature.					
Signature	/mcc/			Date (YYYY-MM-DD)	2008-02-05
First Name	Mark	Last Name	Comtois	Registration Number	46285

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UNITED STATES PATENT APPLICATION

of

MARTIN ALLES

JOHN CARLSON

GEORGE MAHER

and

SELCUK MAZLUM

for

SYSTEM AND METHOD FOR GENERATING A LOCATION ESTIMATE USING UNIFORM AND NON-UNIFORM GRID POINTS

Cross Reference to Related Applications

[0001] The present application claims priority benefit to and hereby incorporates by reference in its entirety co-pending U.S. Provisional Patent Application Serial Number 60/899,379 filed on 5 February 2007.

Background

[0002] The present subject matter is directed generally towards a system and method for estimating the location of a wireless mobile device that is in communication with a wireless communications network. More specifically, the present subject matter relates to the problem of estimating the location of a wireless mobile device using information from one or more Network Measurement Reports ("NMRs") which may be generated by a wireless communications network or the mobile device.

[0003] As is well known in the art, the use of wireless communication devices such as telephones, pagers, personal digital assistants, laptop computers, anti-theft devices, etc., hereinafter referred to collectively as "mobile devices", has become prevalent in today's society. Along with the proliferation of these mobile devices is the safety concern associated with the need to locate the mobile device, for example in an emergency situation. For example, the Federal Communication Commission ("FCC") has issued a geolocation mandate for providers of wireless telephone communication services that puts in place a schedule and an accuracy standard under which the providers of wireless communications must implement geolocation technology for wireless telephones when used to make a 911 emergency telephone call (FCC 94-102 E911). In addition to E911 emergency related issues, there has been increased interest in technology which can determine the geographic position, or "geolocate" a mobile device. For example, wireless telecommunications providers are developing location-enabled services for their subscribers including roadside assistance, turn-by-turn driving directions, concierge services, location-specific billing rates and location-specific advertising.

[0004] Currently in the art, there are a number of different ways to geolocate a mobile device. For example, providers of wireless communication services have installed mobile device location capabilities into their networks. In operation, these network overlay location systems take measurements on radio frequency ("RF") transmissions from mobile devices at base station locations surrounding the mobile device and estimate the location of the mobile device with respect to the base stations. Because the geographic location of the base stations is known, the determination of the location of the mobile device with respect to the base station permits the geographic location of the mobile device to be determined. The RF measurements of the transmitted signal at the base stations can include the time of arrival, the angle of arrival, the signal power, or the unique/repeatable radio propagation path (radio fingerprinting) derivable features. In addition, the geolocation systems can also use collateral information, e.g., information other than that derived for the RF measurement to assist in the geolocation of the mobile device, i.e., location of roads, dead-reckoning, topography, map matching, etc.

[0005] In a network-based geolocation system, the mobile device to be located is typically identified and radio channel assignments determined by (a) monitoring the control information transmitted on radio channel for telephone calls being placed by the mobile device or on a wireline interface to detect calls of interest, i.e., 911, (b) a location request provided by a non-mobile device source, i.e., an enhanced services provider. Once a mobile device to be located has been identified and radio channel assignments determined, the location determining system is first tasked to determine the geolocation of the mobile device and then directed to report the determined position to the requesting entity or enhanced services provider.

[0006] The monitoring of the RF transmissions from the mobile device or wireline interfaces to identify calls of interest is known as "tipping", and generally involves recognizing a call of interest being made from a mobile device and collecting the call setup information. Once the mobile device is identified and the call setup information is collected, the location determining system can be tasked to geolocate the mobile device.

[0007] While the above-described systems are useful in certain situations, there is a need to streamline the process in order to efficiently and effectively handle the vast amount of data being sent between the wireless communications network and the large number of mobile devices for which locations are to be determined. In this regard, the present subject matter overcomes the limitations of the prior art by estimating the location of a wireless mobile device using, at least in part, one or more pre-existing Network Measurement Reports ("NMRs") which include calibration data for a number of locations within a geographic region. The calibration data for these locations must be gathered and analyzed so that particular points (e.g., "grid points") within the geographic region can be determined and associated with a particular set or sets of calibration data from, for example, one or more NMRs. Then, the received signal level measurements reported by the mobile device to be geolocated may be compared with the data associated with the various grid points to estimate the location of the mobile device. The performance of a grid-based pattern matching system such as that disclosed herein is typically dependent on stored received signal level measurements that accurately reflect the levels that are likely to be reported by the mobile device to be located. These grid points do not necessarily have to be part of a uniform grid and usually will not be uniformly distributed throughout the geographic region. These non-uniform grid points ("NUGs"), once determined, can be assigned geographic coordinates so that the NUGs may be used in determining the location of a mobile device exhibiting certain attributes as discussed in more detail below.

[0008] Accordingly, an embodiment of the present subject matter provides a method for assigning geographical coordinates to a grid point located in a geographic region for the location of a mobile device where the method provides calibration data for each of one or more calibration points in the geographic region and where for each of the calibration points the associated calibration data is evaluated and based on that evaluation a determination is made as to whether at least one grid point should be defined, and if so, geographical coordinates are assigned to the grid point.

[0009] An additional embodiment of the present subject matter further includes in the above method a determination of geographical coordinates for each of a plurality of nodes of a uniform grid spanning the geographic region and for each of the grid points determining a closest node from the plurality of nodes and assigning characteristic data associated with the grid point to the closest node.

[0010] A further embodiment includes a method of assigning geographical coordinates to a grid point located in a geographic region for the location of a mobile device where calibration data for each of one or more calibration points in the geographic region are provided, and where for the calibration data associated with each of the calibration points the calibration data is evaluated, a determination is made based on the evaluation as to whether at least one grid point should be defined, and geographical coordinates are assigned to the grid point.

[0011] In another embodiment of the present subject matter, a system for assigning geographical coordinates to a grid point located in a geographic region is presented where the system includes a database and a processor for receiving calibration data for each of one or more calibration points in the geographic region and for each of the calibration points the processor is programmed to evaluate the associated calibration data, determine if at least one grid point should be defined based on the evaluation, assign geographical coordinates to the at least one grid point, and populate the database with the geographical coordinates.

[0012] A further embodiment of the present subject matter includes in the above system circuitry for determining geographical coordinates for each of a plurality of nodes of a uniform grid spanning the geographic region, and circuitry for determining, for each of the at least one grid point, a closest node from the plurality of nodes and assigning characteristic data associated with the grid point to the closest node.

[0013] Yet another embodiment of the present subject matter provides a method of locating a mobile device. The method comprises the steps of providing a plurality of grid

points in a geographic region, providing a plurality of network measurement reports for a mobile device in the geographic region, and comparing ones of the plurality of grid points to at least one parameter of ones of the plurality of network measurement reports. The method further includes generating a first location estimate of the mobile device for each of the ones of said plurality of network measurement reports, and determining a second location estimate of the mobile device as a function of at least one of the generated first location estimates. An additional embodiment includes the step of identifying and omitting outlier first location estimates by determining a Mahalanobis distance from each first location estimate to the second location estimate, determining a distance threshold from a median of the Mahalanobis distances multiplied by a predetermined factor, and determining a third location estimate by averaging two or more of said first location estimates. Another embodiment may also interpolate between ones of the plurality of grid points when more than one grid point corresponds to the at least one parameter of the plurality of network measurement reports. An additional embodiment may provide a default location for the second location estimate if a second location estimate cannot be determined as a function of at least one of the generated first location estimates.

[0014] An additional embodiment of the present subject matter provides a method of improving a location estimate of a mobile device. The method comprises the steps of providing a plurality of grid points in a geographic region, providing a set of network measurement reports for a mobile device in the geographic region, the set of network measurement reports including one or more subsets of network measurement reports, and comparing ones of the plurality of grid points to at least one parameter of a subset of the network measurement reports. The method further includes generating a first location estimate of the mobile device for each subset of network measurement reports, determining a second location estimate of the mobile device as a function of at least one of the generated first location estimates, and indicating an attribute of the second location estimate as a function of a parameter of a subset of the network measurement reports.

[0015] Another embodiment of the present subject matter provides a method of locating a mobile device in a geographic region. The method comprises the steps of providing a plurality of grid points in a geographic region, each of the grid points including at least one characterizing parameter and each of the grid points located on a grid defined over the geographic region and providing a plurality of network measurement reports for a mobile device in the geographic region. The method also comprises determining an estimated location for the mobile device from one network measurement report as a function of the at least one parameter.

[0016] An additional embodiment of the present subject matter provides a method of locating a mobile device in a geographic region. The method comprises the steps of providing a plurality of grid points in a geographic region, each of the grid points including at least one characterizing parameter and each of the grid points located on a grid defined over the geographic region and providing a plurality of network measurement reports for a mobile device in the geographic region. The method also comprises determining an estimated location for the mobile device from a set of said plurality of network measurement reports as a function of the parameter.

[0017] Yet another embodiment of the present subject matter provides another method of estimating the location of a mobile device in a geographic region. The method comprises the steps of providing calibration data for each of one or more calibration points in a geographic region where the calibration data includes at least one characterizing parameter. A candidate network measurement report or set of network measurement reports may be received from a mobile device at an unknown location, where the network measurement report also includes at least one characterizing parameter. The method further comprises defining a first region as a function of a first characterizing parameter and a predetermined range of said first parameter. A second region may be defined as a function of another characterizing parameter and a predetermined range of another parameter. These steps may be repeated for each characterizing parameter in the calibration data and an intersection of each defined region

determined. The location of a mobile device may then be estimated in the geographic region as a function of the intersection.

[0018] In a further embodiment of the present subject matter, a method of estimating the location of a mobile device in a geographic region is provided. The method may comprise the steps of providing one or more sets of calibration data for a plurality of calibration points in a geographic region where the calibration data includes at least one characterizing parameter and for each of select ones of the calibration points the calibration data includes plural data vectors. The method may also include receiving a candidate network measurement report or set of network measurement reports from a mobile device at an unknown location, where the network measurement report also includes at least one characterizing parameter. The method also includes defining a first region as a function of a first characterizing parameter and a predetermined range of the first parameter for a select one set of calibration data, and for the set of calibration data, defining a second region as a function of another characterizing parameter and a predetermined range of the another parameter. These steps may be repeated for each characterizing parameter in the set of calibration data and a clustering of the plural data vectors may be determined. The location of a mobile device may be estimated in the geographic region as a function of the clustering.

[0019] Another embodiment of the present subject matter provides a method of estimating the location of a mobile device in a geographic region comprising providing calibration data for each of one or more calibration points in a geographic region where the calibration data includes at least one characterizing parameter and receiving a set of network measurement reports from a mobile device at an unknown location where at least one of the network measurement reports in the set also includes at least one characterizing parameter. The method may also comprise determining a representative value for each available characterizing parameter in the set as a function of a variation of the available characterizing parameter in each network measurement report in the set and determining one or more representative network measurement reports as a function of the

representative value. The method may then estimate the location of a mobile device in the geographic region as a function of the one or more representative network measurement reports.

[0020] One embodiment of the present subject matter provides a system for estimating the location of a mobile device in a geographic region comprising a database and a processor for receiving calibration data for each of one or more calibration points in a geographic region, the calibration data having at least one characterizing parameter and receiving a candidate network measurement report or set of network measurement reports from a mobile device at an unknown location, where the network measurement report also includes at least one characterizing parameter. The processor may be programmed to determine a first region as a function of a first characterizing parameter and a predetermined range of the first parameter and repeat the determination for each characterizing parameters in the calibration data. The processor may be further programmed to determine an intersection for each defined region, and estimate the location of a mobile device in the geographic region as a function of the intersection.

[0021] Another embodiment of the present subject matter provides a system for estimating the location of a mobile device in a geographic region comprising a database and a processor for receiving calibration data for each of one or more calibration points in a geographic region where the calibration data may include at least one characterizing parameter. The processor may also receive a set of network measurement reports from a mobile device at an unknown location, at least one of the network measurement reports in the set may also include at least one characterizing parameter. The processor may be programmed to determine a representative value for each available characterizing parameter in the set as a function of a variation of the available characterizing parameter in each network measurement report in the set, determine one or more representative network measurement reports as a function of the representative value, and estimate the location of a mobile device in the geographic region as a function of the one or more representative network measurement reports.

[0022] One embodiment of the present subject matter provides a method of determining the location of a mobile device in a geographic region. The method may comprise providing calibration data for each of one or more calibration points in a geographic region where the calibration data includes one or more characterizing parameters and generating one or more sets of grid points for the calibration data. At least one network measurement report may be received from a mobile device at an unknown location and the network measurement report may be evaluated with each of the sets of grid points as a function of select ones of the characterizing parameters. A set of grid points may be selected as a function of a predetermined criteria, and the location of a mobile device in the geographic region may be determined as a function of the selected set of grid points. Additionally, the final estimated location may also be determined as a function of the estimated locations determined within each of the individual sets of grid points.

[0023] Another embodiment of the present subject matter includes a system for determining the location of a mobile device in a geographic region. The system comprises a database and a processor for receiving calibration data for each of one or more calibration points in a geographic region and receiving at least one network measurement report from a mobile device at an unknown location in the geographic region where the calibration data and network measurement report include at least one characterizing parameter. The processor may be programmed to generate one or more sets of grid points for the calibration data and evaluate the at least one network measurement report with each of the sets of grid points as a function of select ones of the characterizing parameters. The processor may further be programmed to select a set of grid points as a function of a predetermined criteria, and determine the location of a mobile device in the geographic region as a function of the selected set. Additionally, the final estimated location may also be determined as a function of the estimated locations determined within each of the individual sets of grid points.

[0024] These embodiments and many other objects and advantages thereof will be readily apparent to one skilled in the art to which the invention pertains from a perusal of the claims, the appended drawings, and the following detailed description of the embodiments.

Brief Description of the Drawings

[0025] Figure 1 is a flow chart for a method for assigning geographical coordinates according to an embodiment of the present subject matter.

[0026] Figure 2 is a flow chart for a method for assigning geographical coordinates including a calibration point according to an embodiment of the present subject matter.

[0027] Figure 3 is a flow chart for a method for assigning geographical coordinates including calibration data according to an embodiment of the present subject matter.

[0028] Figure 4 is a flow chart for a method for assigning geographical coordinates including clustering of data according to an embodiment of the present subject matter.

[0029] Figure 5 is a flow chart for a method for assigning geographical coordinates including clustering of data vectors according to an embodiment of the present subject matter.

[0030] Figure 6 is a flow chart for a method for assigning geographical coordinates including clustering according to an embodiment of the present subject matter.

[0031] Figure 7 is a flow chart for a method for assigning geographical coordinates including determining outliers according to an embodiment of the present subject matter.

[0032] Figure 8 is a flow chart for a method for assigning geographical coordinates including clustering of data vectors at the same calibration point according to an embodiment of the present subject matter.

[0033] Figure 9 is a flow chart for a method for assigning geographical coordinates including clustering of data vectors at the same calibration point according to an embodiment of the present subject matter.

[0034] Figure 10 is a flow chart for a method for assigning geographical coordinates to a grid point according to an embodiment of the present subject matter.

[0035] Figure 11 is a flow chart for a method for assigning geographical coordinates including assigning geographical coordinates to a grid point where only one calibration point is in a geographic region according to an embodiment of the present subject matter.

[0036] Figure 12 is a flow chart for a method for assigning geographical coordinates including assigning geographical coordinates to a grid point where there are plural calibration points in a geographic region according to an embodiment of the present subject matter.

[0037] Figure 13 is a flow chart for a method for assigning geographical coordinates including calibration data information according to an embodiment of the present subject matter.

[0038] Figure 14 is a flow chart for a method for assigning geographical coordinates including evaluating calibration data according to an embodiment of the present subject matter.

[0039] Figure 15 is a flow chart for a method for assigning geographical coordinates including populating a database with the geographical coordinates according to an embodiment of the present subject matter.

[0040] Figure 16 is a flow chart for a method for assigning geographical coordinates including database information according to an embodiment of the present subject matter.

[0041] Figure 17 is a flow chart for a method for assigning geographical coordinates including determining geographical coordinates for nodes of a uniform grid according to an embodiment of the present subject matter.

[0042] Figure 18 is a flow chart for a method for assigning geographical coordinates including characteristic data to nodes of uniform grid according to an embodiment of the present subject matter.

[0043] Figure 19 is a flow chart for a method for assigning geographical coordinates for calibration data for each of one or more calibration points in a geographic region according to an embodiment of the present subject matter.

[0044] Figure 20 is a block diagram for a system for assigning geographical coordinates according to an embodiment of the present subject matter.

[0045] Figure 21 is a block diagram for a system for assigning geographical coordinates including a determination of clustering of plural data vectors according to an embodiment of the present subject matter.

[0046] Figure 22 is a block diagram for a system for assigning geographical coordinates including comparing clusters of data vectors from different calibration points according to an embodiment of the present subject matter.

[0047] Figure 23 is a block diagram for a system for assigning geographical coordinates including comparing clusters of data vectors from the same calibration point according to an embodiment of the present subject matter.

[0048] Figure 24 is a block diagram for a system for assigning geographical coordinates including calibration data according to an embodiment of the present subject matter.

[0049] Figure 25 is a block diagram for a system for assigning geographical coordinates including evaluating calibration data according to an embodiment of the present subject matter.

[0050] Figure 26 is a block diagram for a system for assigning geographical coordinates including information for populating a database according to an embodiment of the present subject matter.

[0051] Figure 27 is a block diagram for a system for assigning geographical coordinates including circuitry for determining geographical coordinates for nodes of a uniform grid according to an embodiment of the present subject matter.

[0052] Figure 28 is a block diagram for a system for assigning geographical coordinates including characteristic data according to an embodiment of the present subject matter.

[0053] Figure 29 is a flow chart for a method for locating a mobile device according to one embodiment of the present subject matter.

[0054] Figure 30 is a flow chart for a method for locating a mobile device according to one embodiment of the present subject matter including identifying and omitting outlier first location estimates.

[0055] Figure 31 is a flow chart for a method for locating a mobile device according to another embodiment of the present subject matter.

[0056] Figure 32 is a flow chart for a method for locating a mobile device according to one embodiment of the present subject matter including omitting a first location estimate.

[0057] Figure 33 is a flow chart for a method for locating a mobile device according to one embodiment of the present subject matter including interpolating between grid points.

[0058] Figure 34 is a flow chart for a method for locating a mobile device according to another embodiment of the present subject matter including interpolating between grid points and/or assigning weights to selected grid points.

[0059] Figure 35 is a flow chart for a method for locating a mobile device according to another embodiment of the present subject matter including providing a default location.

[0060] Figure 36 is a flow chart for a method of improving a location estimate of a mobile device.

[0061] Figure 37 is a flow chart for a method of improving a location estimate of a mobile device according to another embodiment of the present subject matter.

[0062] Figure 38 is a flow chart for a method of improving a location estimate of a mobile device according to another embodiment of the present subject matter including omitting a first location estimate.

[0063] Figure 39 is a flow chart for a method for locating a mobile device according to one embodiment of the present subject matter including identifying and omitting outlier first location estimates.

[0064] Figure 40 is a flow chart for a method of improving a location estimate of a mobile device according to a further embodiment of the present subject matter.

[0065] Figure 41 is a flow chart for a method of improving a location estimate of a mobile device according to a further embodiment of the present subject matter including providing a default location.

[0066] Figures 42-55 are flow charts for methods of locating a mobile device in a geographic region according embodiments of the present subject matter.

[0067] Figures 56-64 are flow charts for methods of estimating the location of a mobile device in a geographic region according to embodiments of the present subject matter.

[0068] Figures 65-66 are diagrams for systems for estimating the location of a mobile device in a geographic region according to embodiments of the present subject matter.

[0069] Figures 67-69 are flow charts for methods of determining the location of a mobile device in a geographic region according to embodiments of the present subject matter.

[0070] Figures 70-72 are diagrams for systems for determining the location of a mobile device in a geographic region according to embodiments of the present subject matter.

Detailed Description

[0071] With reference to the Figures where generally like elements have been given like numerical designations to facilitate an understanding of the present subject matter, the various embodiments of a system and method for generating a location estimate using uniform and non-uniform grid points are herein described.

[0072] The following description of the present subject matter is provided as an enabling teaching of the present subject matter and its best, currently-known embodiment. Those skilled in the art will recognize that many changes can be made to the embodiments described herein while still obtaining the beneficial results of the present subject matter. It will also be apparent that some of the desired benefits of the present subject matter can be obtained by selecting some of the features of the present

subject matter without utilizing other features. Accordingly, those who work in the art will recognize that many modifications and adaptations of the present subject matter are possible and may even be desirable in certain circumstances and are part of the present subject matter. Thus, the following description is provided as illustrative of the principles of the present subject matter and not in limitation thereof. While the following exemplary discussion of embodiments of the present subject matter may be directed primarily towards calibration data, it is to be understood that the discussion is not intended to limit the scope of the present subject matter in any way and that the principles presented are equally applicable to other types of data, *e.g.,* signal strength, GPS, NMR, Cell-ID, TDOA, RTT, TA, AOA, etc., capable of being delivered by components in a communications network such as a base station, location measurement unit, other mobile devices, etc. In addition, the use of various combinations of all of these sources, as in a hybrid location scheme, is within the scope of the subject matter disclosed herein.

[0073] The present subject matter is directed generally to the problem of estimating the location of a wireless mobile device using calibration data contained in one or more Network Measurement Reports ("NMRs"). The calibration data for various points must be gathered and analyzed so that particular points (e.g., "grid points") within the geographic region can be determined and associated with a particular set or sets of calibration data from, for example, one or more NMRs. In order to do so geographic coordinates may be assigned to grid points located in a geographic region. The grid points may be non-uniformly spaced throughout the geographic region and hence may be referred to as non-uniform grid points ("NUGs"). The location of a wireless mobile device may be estimated by comparing data reported by the mobile device to be geolocated with the data (and more particularly the characteristics derived from this data) associated with the various grid points to thereby estimate the location of the mobile.

[0074] The system and/or method of the present subject matter may apply to the situation where calibration data is available over discrete points in a 2-dimensional region "R" (3-D region is also contemplated such as within large multi-level structures). The

calibration data may be contained within a Network Measurement Report ("NMR") as is known in the art or the calibration data may be obtained using other known methods. The calibration data may be obtained at each of several calibration points, which may be discrete points within region R each having geographical coordinates (e.g., latitude and longitude) associated therewith. The calibration data may include, but is not limited to, the following: (a) signal strengths observed for signals transmitted by a set of transmitters of known location within or in proximity to the region R; (b) signal strength of a transmitter located at the calibration point as measured by a set of receivers of known location within or in proximity to the region R; (c) round trip time for a signal between the calibration point and an external known point; (d) time difference of arrival at the calibration point with respect pairs of external points located within or in proximity to region R as measured by either a receiver at the calibration point or the external points; (e) the serving cell or sector for a mobile wireless device operating at that calibration point; (f) the network state at the time of collection – a finite number of such states may be required to distinguish between network conditions that vary diurnally, weekly or in some other manner; and (g) combinations of the above.

[0075] As a non-limiting example, the case in (a) may apply to the Integrated Digital Enhanced Network ("IDEN") specification, (c) may apply to the Global System for Mobile communications ("GSM") specification as in the Timing Advance ("TA") parameter or the Round Trip Time ("RTT") parameter in the Universal Mobile Telecommunications System ("UMTS") specification, (d) may apply to the UMTS specification, while the external receivers may be the base stations. In general, the calibration data may be any of those measurements made by a mobile wireless device located at the calibration point or any measurement made on the transmissions or characteristics of the mobile wireless device at a set of external transmitter/receivers in the region R or in proximity thereto.

[0076] The calibration data may consist of many such sets (i.e., vectors) obtained at one or more calibration points. At each calibration point, the data gathering may have

resulted in either a single data vector or multiple data vectors, so that there are potentially multiple sets of data and/or data vectors associated with each calibration point.

[0077] A NUG generator or a method to produce NUGs may begin the NUG generation operation using, for example, one of more of the following: (a) a fixed uniform grid ("UG") defined over the region R with the calibration point data being assigned to the fixed grid points by some rule (e.g., allocated by closest fixed grid point, a centroid of a set of fixed grid points, etc.); (b) random grid points to define the start of each NUG; (c) combinations of (a) and (b) depending on the characteristics of the calibration data; or (d) some other useful method.

[0078] In any of these cases, the NUG generator may evaluate the data vectors at a particular (candidate) calibration point, or at a fixed grid point to which the data vector(s) is/are assigned. This calibration point or grid point may serve as the root of a first NUG. The root of the NUG may be the calibration data vector that initiates the creation of that NUG. The vectors may be examined using, for example, increasingly stringent tests of statistical sufficiency. In particular, a determination may be made as to whether the data vectors exhibit clustering. If the data exhibits tight clustering, the data for the next candidate calibration point may be aggregated to the former calibration point and the clustering property may be re-evaluated. For example, if the second calibration point also has a cluster but this cluster is sufficiently different than the cluster of the first calibration point, a determination may be made that the data for the two considered calibration points should be allocated to the roots of separate NUGs. If the aggregate cluster (i.e., a cluster including data from both the first and second calibration points) is statistically very similar to either of the first or second clusters (taken independently), then the data for the two calibration points may be allocated to the same NUG. All adjacent calibration data points may be similarly evaluated with respect to the first considered calibration point. Thus one or more of the adjacent calibration points may either wind up having all their data accumulated into a single NUG or, at the other extreme, each such calibration point may become the root of a separate NUG.

[0079] The primary test made to determine the allocation may be one of a variety of clustering tests, such as, for example, the K-means algorithm. Statistical similarity may be determined by, for example, the probability density function ("pdf") of the data parameters (e.g., neighboring cell signal levels, timing information, etc.), the mean and variance of the data parameters, the serving cell/sector, or other functions of the calibration data.

[0080] Those measurements or parameter values that do not cluster may be referred to as outliers. The performance of a grid-based pattern matching system such as that disclosed herein is typically dependent on stored received signal level measurements that accurately reflect the levels that are likely to be reported by the mobile device to be located. If the drive test data, for example, used to create the RF signal level grid contains outlier measurements, the statistically consistent value of the signal level will be distorted. Therefore, the present subject matter also describes a system and method used to identify and eliminate outlier signal level measurements and timing advance values (or in general, any parameter within the NMR) during NUG or grid creation so as to improve the estimate of the mean parameter value.

[0081] As a non-limiting example, in a very simple consideration of clustering one could consider the mean value of a parameter. In this scenario, neighbor cell control channel signal level measurement outliers could be eliminated as follows: At each grid point, the average received signal level of a particular control channel signal may be computed from all of the measurements of that signal assigned to the grid point. The deviation of each individual measurement from the mean may be computed. Measurements that deviate by more than a configurable predetermined threshold from the mean may be omitted. The average may then be recomputed without the omitted outliers. In a scenario where there are very few measurements, typically less than five or so, the original mean value will be greatly influenced by any outlier measurements and thus may falsely identify too many of the measurements as outliers, or fail to detect outliers at all.

For this reason, another parameter is used to only perform the outlier check if there are at least a minimum number of measurements.

[0082] In a more general case, a cluster may be a region in N-dimensional NMR vector space where there is a sufficient number of such vectors with a mutual variation such that the mutual variation could be ascribed purely to noise in the measurement. Thus, for example, if within a few feet of the original measurement, if a particular parameter is blocked (say by a large structure such as a building) that parameter would fall out of the original cluster. If sufficient such blocked locations have data falling near the original cluster, one may obtain a secondary cluster where the difference between the first and second clusters is the large variation in this particular parameter.

[0083] In addition, if any of the examined sets of data associated with a calibration point exhibit more than one cluster, it may be necessary to define one or more co-located NUGs. Thus, if there are, for example, three well defined clusters associated with a particular calibration point, these clusters could form the roots of three co-located NUGs. The data in these NUGs may grow depending on whether similar clusters can also be found in adjacent (or close) calibration points in which case the similar clusters may be aggregated to the original NUGs or, if the adjacent clusters are not similar, the adjacent clusters (or cluster) may form separate root NUGs (or NUG).

[0084] Further, if the quantity of data associated with a particular calibration point is insufficient to sensibly test for statistical similarity or clustering, data from adjacent calibration grid points may be accumulated first and the statistical or clustering test performed thereafter. Thus, based on the results of the clustering test using the accumulated data the determination of how one should separate out the data into NUGs may be made.

[0085] The technique may be repeated until all calibration grid points in the region R are exhausted. At the end of this process one has divided the region into a collection of NUGs, where multiple co-located NUGs may exist. The NUGs may fully cover the

region R and each NUG may have statistically similar data accumulated into itself. The geometrical shape (*i.e.*, the shape defined by the union of locations of calibration points assigned to the NUG) and the amount of data accumulated into such NUGs is seen to be variable since these are determined by the statistical similarity of the data allocated to a NUG.

[0086] Additionally, we may also consider the method of generating NUGs based not on statistical consistency of calibration data, but on other conditions such as (a) a minimum number of unique neighbors observed in data accumulated from allocated calibration grid points; (b) a minimum number of data vectors (NMRs); (c) a maximum and/or minimum NUG radius; (d) a specific set of neighboring cells; (e) a specific set of neighboring cells with power ordering; or (f) any combination of the above. Additionally, the method of using statistical consistency or similarity or data clustering combined with any of these other conditions may be employed.

[0087] For each so obtained NUG, a variety of parameters and functions may be generated and stored to describe that NUG. These are termed the NUG characteristics. The NUG characteristics are a representation in that attempt to capture the nature and variability of the data associated with that NUG in a compact and representative form. These characteristics may include, but are not limited to, the following: (a) an ordered list of neighboring cells; (b) functions defined on the absolute neighboring cell power levels (e.g., mean, median, k^{th} moment, cluster-mean, etc.); (c) functions defined on the relative neighboring cell power differences (e.g., mean, median, k^{th} moment, cluster-mean, etc.); (d) serving cell/sector; (e) timing advance parameter (or equivalent); (f) individual pdf (probability density function or probability distribution function) of each neighboring cell power level; (g) joint pdf of neighboring cell power levels; (h) mean and variance of neighboring cell power levels; (i) mobile device orientation (e.g., indoors, outdoors, direction mobile device is facing (e.g., North, South, etc.), tilted upwards, azimuth, elevation, etc.); (j) a compact and/or efficient representation that enables retrieval of the calibration data NMR vectors assigned to this NUG; (k) the network state

as indicated in the calibration data; (l) a confidence measure indicative of the reliability of the calibration data feeding this NUG; and (m) any combinations of the above.

[0088] If a pdf is determined for a NUG, that pdf may be generated using either the Parzen technique or the method of Gaussian mixtures or some variant thereof. In addition when a need to specify the variance or covariance exists, that parameter may be set to a value dependent on the observed variance for a particular neighboring cell power level or the observed covariance matrix for a set of neighboring cell power levels.

[0089] The location ascribed to the NUG may be, for example, any internal point within the NUG. If the NUG contains only a single calibration point, the location of the NUG may be set as the location of the calibration point. If the NUG encompasses several calibration points, the location of any one of the calibration points or the centroid of such calibration points or some other similar measure may be used to define the NUG location. Also, in the case of multiple co-located NUGs, all such NUGs may have their assigned location set to the same value.

[0090] With reference now to Figure 1, a flow chart is depicted for a method for assigning geographical coordinates according to an embodiment of the present subject matter. At block 101, calibration data may be provided for each of one or more calibration points in a geographic region. At block 102, for each of the calibration points calibration data associated with the calibration point is evaluated and a determination is made as to whether a grid point, such as a NUG, should be defined. If it is determined that a grid point is to be defined, geographical coordinates are assigned to the grid point so that the grid point may be useful in estimating the location of a mobile device.

[0091] Figure 2 is a flow chart for a method for assigning geographical coordinates including a calibration point according to an embodiment of the present subject matter. Blocks 201 and 202 are similar to blocks 101 and 102, respectively. At block 213, the calibration point may be located on a predetermined fixed uniform grid defined over the

geographic region or the calibration point may be randomly located within the geographic region.

[0092] Figure 3 is a flow chart for a method for assigning geographical coordinates including calibration data according to an embodiment of the present subject matter. Blocks 301 and 302 are similar to blocks 101 and 102, respectively. At block 313, the calibration data associated with one or more calibration points may be comprised of information from a NMR, or the calibration data for a particular calibration point may be obtained from one or more mobile devices located at or in close proximity to the calibration point, or the calibration data for a particular calibration point may be obtained from a signal transmitted from a mobile device (or devices) located at or in close proximity to the calibration point where the signal is received by a receiver in or in proximity to the geographic region.

[0093] Figure 4 is a flow chart for a method for assigning geographical coordinates including clustering of data according to an embodiment of the present subject matter. Blocks 401 and 402 are similar to blocks 101 and 102, respectively. At block 413, for one or more of the calibration points the calibration data may include multiple data vectors and, at block 414, the evaluation of the data vectors may include a determination of clustering of the multiple data vectors as described above.

[0094] Considering now the flow chart depicted in Figure 5, the flow chart indicates a method for assigning geographical coordinates including clustering of data vectors according to an embodiment of the present subject matter. Blocks 501 and 502 are similar to blocks 101 and 102, respectively. At block 503, the determination of whether at least one grid point should be defined based on the evaluation of the calibration data associated with a calibration point includes a comparison of a first cluster of data vectors from a first calibration point to a second cluster of data vectors where the second cluster of data vectors includes the first cluster of data vectors as well as data vectors from a second calibration point. At block 504, if the comparison in block 503

results in the difference between the first and second cluster of data vectors being within a predetermined tolerance value, then the data vectors from the first and second calibration points are assigned to the same grid point. However, if the comparison is not within tolerance, then the data vectors from the first calibration point are assigned to a first grid point and the data vectors from the second calibration point are assigned to a second grid point.

[0095] The flow chart shown in Figure 6 illustrates another method for assigning geographical coordinates including clustering according to an embodiment of the present subject matter. Here, blocks 601, 602, 603, and 604 are similar to blocks 501, 502, 503, and 504, respectively. At block 615 the evaluation of calibration data for one or more calibration points may include determining the clustering of plural data vectors using a K-means analysis. At block 616 the comparing of clusters of data vectors may include determining a probability density function of an aspect of the data vectors.

[0096] Figure 7 is a flow chart for a method for assigning geographical coordinates including determining outliers according to an embodiment of the present subject matter. Blocks 701, 702, 713, and 714 are similar to blocks 401, 402, 413, and 414, respectively. At block 703, a determination of outlier data vectors may be made and the outlier data vectors may be eliminated from the determination of data vector clustering.

[0097] Regarding Figure 8, a flow chart is represented for a method for assigning geographical coordinates including clustering of data vectors at the same calibration point according to an embodiment of the present subject matter. Blocks 801 and 802 are similar to blocks 101 and 102, respectively. At block 803, the determination if at least one grid point should be defined based on the evaluation of calibration data may include a comparison of a first cluster of data vectors associated with a first calibration point to a second cluster of data vectors associated with the first calibration point. If the result of the comparison is within a predetermined tolerance, then the data vectors from the first and second clusters may be assigned to the same grid point; otherwise, the data vectors

from the first cluster may be assigned to a first grid point while the data vectors from the second cluster may be assigned to a second grid point.

[0098] Figure 9 is a flow chart illustrating another method for assigning geographical coordinates including clustering of data vectors at the same calibration point according to an embodiment of the present subject matter. Here, blocks 901, 902, 903, and 904 are similar to blocks 801, 802, 803, and 804, respectively. At block 915 the geographical coordinates assigned to the first and second grid points may be identical.

[0099] Directing attention now towards Figure 10, a flow chart is presented for a method for assigning geographical coordinates to a grid point according to an embodiment of the present subject matter. Blocks 1001 and 1002 are similar to blocks 101 and 102, respectively. At block 1013, the geographical coordinates assigned to a first grid point may be different than the geographical coordinates assigned to a second grid point or the geographical coordinates assigned to a first grid point may be the same as the geographical coordinates assigned to a second grid point.

[00100] Figure 11 is a flow chart for a method for assigning geographical coordinates including assigning geographical coordinates to a grid point where only one calibration point is in a geographic region according to an embodiment of the present subject matter. Blocks 1101 and 1102 are similar to blocks 101 and 102, respectively. At block 1113, if there is only one calibration point within the geographic region, then the geographical coordinates assigned to a grid point may result in the grid point being located within a predetermined radius of the one calibration point. Or, the geographical coordinates assigned to a grid point may be identical to the geographical coordinates of the calibration point.

[00101] Moving now to Figure 12, a flow chart is shown for a method for assigning geographical coordinates including assigning geographical coordinates to a grid point where there are plural calibration points in a geographic region according to an embodiment of the present subject matter. Blocks 1201 and 1202 are similar to blocks

101 and 102, respectively. At block 1213, where there are multiple calibration points in the geographic region, the geographical coordinates assigned to a grid point may result in the grid point being located within a predetermined radius of a centroid of a polygon formed by connecting the multiple calibration points.

[00102] Figure 13 is a flow chart for a method for assigning geographical coordinates including calibration data information according to an embodiment of the present subject matter. Blocks 1301 and 1302 are similar to blocks 101 and 102, respectively. At block 1313, the calibration data may include one or more of the following: signal strength for a signal transmitted by a transmitter having a known location as received by a receiver at a calibration point; signal strength of a signal transmitted by a transmitter located at a calibration point as received by a receiver at a known location; round trip time for a signal traveling between a calibration point and a known location; timing advance of a signal received by a mobile device at a calibration point; time difference of arrival of plural signals at a calibration point with respect to a pair of known locations as measured by a receiver at a calibration point or at the known locations; the identification of a serving cell or serving sector of a mobile device located at a calibration point; a state of a wireless network serving a mobile device; and combinations thereof.

[00103] Figure 14 is a flow chart for a method for assigning geographical coordinates including evaluating calibration data according to an embodiment of the present subject matter. Blocks 1401 and 1402 are similar to blocks 101 and 102, respectively. At block 1413, the evaluating of the calibration data associated with a calibration point may include an evaluation such as: a minimum number of unique neighboring calibration points as determined by calibration data of the neighboring calibration points; a minimum number of data vectors or network measurement reports; a predetermined maximum or minimum radius from a calibration point; a predetermined set of cells neighboring a cell serving a mobile device; and combinations thereof.

[00104] Figure 15 is a flow chart for a method for assigning geographical coordinates including populating a database with the geographical coordinates according to an embodiment of the present subject matter. Blocks 1501 and 1502 are similar to blocks 101 and 102, respectively. At block 1503, a database may be populated with the geographical coordinates assigned to the grid points.

[00105] Figure 16 is a flow chart for a method for assigning geographical coordinates including database information according to an embodiment of the present subject matter. Blocks 1601, 1602, and 1603 are similar to blocks 1501, 1502, and 1503, respectively. At block 1604, the database may be populated with information such as: a list of cells neighboring a cell serving a mobile device; a quantity that is a function of a power level of one or more cells neighboring a cell serving a mobile device; an identity of a cell or a sector serving a mobile device; a timing advance parameter; a geographical orientation of a mobile device; a location of a mobile device; network measurement report data vectors; a state of a network serving a mobile device; a confidence measure indicative of a reliability of the calibration data; and combinations thereof.

[00106] Directing attention now to Figure 17, a flow chart is presented for a method for assigning geographical coordinates including determining geographical coordinates for nodes of a uniform grid according to an embodiment of the present subject matter. Blocks 1701 and 1702 are similar to blocks 101 and 102, respectively. At block 1703, geographical coordinates may be determined for the nodes of a uniform grid spanning the geographic region. At block 1704, for each of the grid points, a determination of the closest node of the uniform grid is made and the characteristic data associated with the grid point may be assigned to the closest node.

[00107] Further, Figure 18 is a flow chart for a method for assigning geographical coordinates including characteristic data to nodes of uniform grid according to an embodiment of the present subject matter. Here, blocks 1801, 1802, 1803, and 1804 are similar to blocks 1701, 1702, 1703, and 1704, respectively. At block 1805, the

characteristic data may include a list of cells neighboring a cell serving a mobile device; a quantity that is a function of a power level of one or more cells neighboring a cell serving a mobile device; an identity of a cell or a sector serving a mobile device; a timing advance parameter; a geographical orientation of a mobile device; a location of a mobile device; network measurement report data vectors; a state of a network serving a mobile device; a confidence measure indicative of a reliability of the calibration data; and combinations thereof.

[00108] With reference to Figure 19, a flow chart is illustrated for a method for assigning geographical coordinates for calibration data for each of one or more calibration points in a geographic region according to an embodiment of the present subject matter. At block 1901, calibration data may be provided for each of one or more calibration points in a geographic region. At block 1902, for the calibration data for each of the calibration points in the geographic region, the calibration data is evaluated and a determination is made as to whether a grid point should be defined based on the evaluation. If it is determined that a grid point is to be defined, geographical coordinates are assigned to the grid point so that the grid point may be useful in estimating the location of a mobile device.

[00109] With attention now directed to Figure 20, a block diagram is presented that represents a system for assigning geographical coordinates according to an embodiment of the present subject matter. A database 2001 is operatively connected to a processor 2002. The processor 2002 is capable of receiving calibration data for each of one or more calibration points in a geographic region. The processor 2002 may be programmed, as shown in block 2003, to evaluate the calibration data associated with the calibration points, determine if at least one grid point should be defined based on the evaluation, assign geographical coordinates to the one or more grid points, and populate the database 2001 with the geographical coordinates.

[00110] Figure 21 is a block diagram for a system for assigning geographical coordinates including a determination of clustering of plural data vectors according to an embodiment of the present subject matter. The database 2101, the processor 2102, and block 2103 are similar to the database 2001, the processor 2002, and block 2003, as described above, respectfully. At block 2114, for each of select ones of the calibration points, the calibration data may include multiple data vectors and the evaluating of the calibration data may include a determination of clustering of the multiple data vectors.

[00111] Figure 22 is a block diagram for a system for assigning geographical coordinates including comparing clusters of data vectors from different calibration points according to an embodiment of the present subject matter. The database 2201, the processor 2202, block 2203, and block 2214 are similar to the database 2101, the processor 2102, block 2103, and block 2114, as described above, respectfully. At block 2215, the determination if at least one grid point should be defined based on the evaluation may include comparing a first cluster of data vectors from a first one of the select calibration points to a second cluster of data vectors, where the second cluster of data vectors may include the first cluster of data vectors and data vectors from a second one of the select calibration points. At block 2216, if the result of the comparison is within a predetermined tolerance, then the data vectors from the first and second calibration points may be assigned to the same grid point; otherwise, the data vectors from the first calibration point may be assigned to a first grid point and the data vectors from the second calibration point may be assigned to a second grid point.

[00112] Figure 23 is a block diagram for a system for assigning geographical coordinates including comparing clusters of data vectors from the same calibration point according to an embodiment of the present subject matter. The database 2301, the processor 2302, block 2303, and block 2314 are similar to the database 2101, the processor 2102, block 2103, and block 2114, as described above, respectfully. At block 2315, the determination if at least one grid point should be defined based on the evaluation may include comparing a first cluster of data vectors from a first one of the

select calibration points to a second cluster of data vectors from the first one of the select calibration points. At block 2316, if the result of the comparison is within a predetermined tolerance, then the data vectors from the first and second calibration points may be assigned to the same grid point; otherwise, the data vectors from the first cluster may be assigned to a first grid point and the data vectors from the second cluster may be assigned to a second grid point.

[00113] Looking now at Figure 24, a block diagram is presented representing a system for assigning geographical coordinates including calibration data according to an embodiment of the present subject matter. The database 2401, the processor 2402, and block 2403 are similar to the database 2001, the processor 2002, and block 2003, as described above, respectfully. At block 2414, the calibration data may include: signal strength for a signal transmitted by a transmitter having a known location as received by a receiver at a calibration point; signal strength of a signal transmitted by a transmitter located at a calibration point as received by a receiver at a known location; round trip time for a signal traveling between a calibration point and a known location; timing advance of a signal received by a mobile device at a calibration point; time difference of arrival of multiple signals at a calibration point with respect to a pair of known locations as measured by a receiver at a calibration point or at the known locations; the identification of a serving cell or serving sector of a mobile device located at a calibration point; a state of a wireless network serving a mobile device, and combinations thereof.

[00114] Figure 25 is a block diagram for a system for assigning geographical coordinates including evaluating calibration data according to an embodiment of the present subject matter. The database 2501, the processor 2502, and block 2503 are similar to the database 2001, the processor 2002, and block 2003, as described above, respectfully. At block 2514, the evaluation of the associated calibration data may include an evaluation such as: a minimum number of unique neighboring calibration points as determined by calibration data of the neighboring calibration points; a minimum number of data vectors or network measurement reports; a predetermined maximum or minimum

radius from a calibration point; a predetermined set of cells neighboring a cell serving a mobile device; and combinations thereof.

[00115] Figure 26 is a block diagram for a system for assigning geographical coordinates including information for populating a database according to an embodiment of the present subject matter. The database 2601 and the processor 2602 are similar to the database 2001 and the processor 2002, as described above, respectfully. At block 2603, the processor 2602 may be programmed to evaluate the calibration data associated with the calibration points, determine if at least one grid point should be defined based on the evaluation, assign geographical coordinates to the one or more grid points, populate the database 2601 with the geographical coordinates, and populate the database 2601 with information which may include: a list of cells neighboring a cell serving a mobile device; a quantity that is a function of a power level of one or more cells neighboring a cell serving a mobile device; an identity of a cell or a sector serving a mobile device; a timing advance parameter; a geographical orientation of a mobile device; a location of a mobile device; network measurement report data vectors; a state of a network serving a mobile device; a confidence measure indicative of a reliability of the calibration data; and combinations thereof.

[00116] Figure 27 is a block diagram for a system for assigning geographical coordinates including circuitry for determining geographical coordinates for nodes of a uniform grid according to an embodiment of the present subject matter. The database 2701, the processor 2702, and block 2703 are similar to the database 2601, the processor 2602, and block 2603, as described above, respectfully. The system may further comprise circuitry 2704 for determining geographical coordinates for each of a plurality of nodes of a uniform grid spanning the geographic region, and circuitry 2705 for determining, for each of the one or more grid points, a closest node from the plurality of nodes of the uniform grid and assigning characteristic data associated with each of the grid point to its closest node.

[00117] Figure 28 is a block diagram for a system for assigning geographical coordinates including characteristic data according to an embodiment of the present subject matter. The database 2801, the processor 2802, block 2803, circuitry 2804, and circuitry 2805 are similar to the database 2701, the processor 2702, block 2703, circuitry 2704, and circuitry 2705, as described above, respectfully. At block 2816, the characteristic data may include: a list of cells neighboring a cell serving a mobile device; a quantity that is a function of a power level of one or more cells neighboring a cell serving a mobile device; an identity of a cell or a sector serving a mobile device; a timing advance parameter; a geographical orientation of a mobile device; a location of a mobile device; network measurement report data vectors; a state of a network serving a mobile device; a confidence measure indicative of a reliability of the calibration data; and combinations thereof.

[00118] In a typical signal strength pattern matching mobile location system the time allowed to produce a location may be such that multiple NMRs and sets and subsets thereof may be available. By way of a non-limiting example, in the GSM air standard, mobile measurements are reported at an approximate rate of approximately two per second. Generally, the time allowed to produce a location may be on the order of thirty seconds. It is therefore an aspect of embodiments of the present subject matter to improve location accuracy by combining individual locations from calibration data, *e.g.,* multiple NMRs, to produce a final location estimate.

[00119] Grid-based signal strength pattern matching location systems typically determine a quantitative measure of how close each candidate grid point matches with mobile-reported measurement parameters. An estimate of a mobile device's location may then be given by a grid point having the closest match thereto or a location interpolated between several grid point locations. As multiple NMRs are generally available during the time allotted to report the estimated location of a mobile device, embodiments of the present subject matter may utilize each NMR to generate an independent location estimate. These independent or individual location estimates may

then be averaged or another mathematical function employed thereon to produce a final estimated mobile location that may be statistically more accurate.

[00120] Many location systems may also "fall back" to a default location as a function of the serving cell when the system is unable to determine a grid point match location. In such an instance, a location status variable may be utilized to identify the default location as a fall back location. Such a fall back location is generally less accurate than a location estimate determined by a pattern matching location system; however, an exemplary location combiner may omit any fall back locations and average or combine location estimates determined by an exemplary pattern matching algorithm.

[00121] A correlation may exist between location accuracy and mismatch distance metrics, *e.g.*, "cost" values. The correlation may be exploited by flagging individual location estimates as having a high cost or metric (*e.g.*, using a location status variable), and the corresponding location estimates are likely to possess a large location error. Embodiments of the present subject matter may present a refinement to the location combiner by skipping or omitting individual locations exceeding a predetermined "cost" threshold. Thus, the resulting location accuracy may be significantly improved. In further embodiments, the correlation between mismatch distance metrics and location accuracy may be exploited by employing weighted averaging of the individual estimated locations, weighting by an inverse of the metrics, normalizing by a sum of the inverses, or any combination thereof. A further metric that may be utilized for weighting the contribution of individual location estimates to a final location estimate may be the number of reporting neighboring cells. By way of a non-limiting example, assuming five individual location estimates are combined and four of the five individual location estimates possessed six reporting neighboring cells and the fifth location estimate possessed four reporting neighboring cells, the fifth location estimate may then be de-weighted in the final location estimation.

[00122] Another embodiment of the present subject matter may identify and omit outlier individual location estimates to improve the final location estimation. For example, a Mahalanobis distance from each individual location estimate to the final location estimate may be determined. A dynamic distance threshold may be determined from the median of these distances multiplied by a configurable factor. An individual location estimate having a distance to the final location estimate exceeding the threshold may be identified as an outlier. The final location estimate may then be re-determined with the outlier locations omitted. In the event that weighted averaging is utilized in such a determination, the weights may be re-determined prior to the final location estimation.

[00123] It may also be noted that estimated locations derived utilizing subsets of available NMRs may often differ. For example, considering an NMR including a set of ordered (*e.g.,* in descending magnitude) reporting neighboring cell (NC) power levels, with the NC having an order ABCDE. If the lowest power NC (NC=E) is omitted from the NMR, the locations determined using ABCD NCs may be different from ABCDE. Similarly, the location determined for ABCE NCs may differ from that for ABDE NCs.

[00124] An examination or evaluation of the location estimates derived from subsets of the NMRs may provide an indication regarding the quality of the final location estimate. By way of a non-limiting example, if the location estimates derived utilizing any possible method of mapping the NMR or sets thereof to a specific geographic location or grid point, whether using NUGs or uniform grid points, agree under combinations of subsets, the confidence in the location estimate may be high and thus represent a confidence measure on the location estimate. Further, the fraction of total location estimates within a predetermined distance of the final location estimate may also qualify as a confidence measure.

[00125] In one embodiment of the present subject matter, for each NMR, one may form a set of all subsets of a selected NMR. Therefore, in a non-limiting example of an ordered set of NCs given by ABC, a full set of subsets is {ABC, AB, AC, BC, A, B, C}.

In each case, an estimated location may be derived utilizing any method of location. Each of the locations in this set of locations, L, may possess an associated probability or other measure derived from the particular location method, thus defining a set M. A variety of schemes may be defined and implemented upon the set L and the set of associated measures on L, given by M, such as, but not limited to: (a) computing the final estimated location by clustering the set L without any reference to the measures in M; (b) computing the final estimated location as the centroid of a region containing the tightest cluster in L having an aggregate measure higher than some pre-set value; (c) computing the final estimated location as the location of the NUG (*e.g.,* centroid of the NUG) which occurs most often in L; (d) computing the final estimated location by clustering the subset of L obtained by dropping the least power member in the NMR successively (*e.g.,* the subset {ABC, AB, A}); (e) computing the final estimated location as the subset of L obtained by successively dropping the least power member in the NMR and with weighting by the corresponding measure in M.

[00126] Considering that the individual marginal probabilities for each NMR component, characteristic or parameter over a set of candidate NUGs or uniform grid points (UG) have been determined, it may be assumed that for every subset in L, the measure set M provides the joint probability for the subsets of the NMR. Using the subset AB in the previous example, the marginal probability for A, B and C over all NUGs has been determined. To determine the joint probability of A and B, for example, the marginal probabilities for A and B may be multiplied over the NUGs (or other locations). This generates the measure set M, and having the set L and set M defined, any one or combination of the methods in (a)-(e) described in the previous paragraph may be applied thereto for an estimation of an exemplary confidence measure.

[00127] The same principles may be applied to multiple NMRs and each of their respective subsets where each subset of each NMR may be assigned its respective measure in a now larger set M. It follows that the methods in (a)-(e) described above are equally applicable. In the case of multiple NMRs, a representative NMR may be

determined through a clustering algorithm applied to each parameter of the NMR viewed over the set of NMRs. The methods in (a)-(e) described above may then be applied to this representative NMR for an estimation of an exemplary confidence measure.

[00128] It is also an aspect of embodiments of the present subject matter to provide an estimate of the location error in a signal strength pattern matching location system. As discussed above, a confidence measure may be determined that provides an indication of the quality of the location estimate.

[00129] In one embodiment of the present subject matter, if the final estimated location is an average of the individual locations, the degree to which the individual locations are clustered around the final estimation may provide an indication of the location error. The error estimate may be determined as the average of the distances from each individual location to the final estimated location as a function of the following relationship:

$$\hat{e} \equiv \frac{\sum_{i=1}^{N} d_i}{N} \qquad (1)$$

where N is the number of estimated locations and d_i is the Euclidean distance from the ith estimated location to the final estimated location.

[00130] The error estimate may also be determined as a function of the following relationship:

$$\hat{e} \equiv \frac{\sum_{i=1}^{N} w_i d_i}{\sum_{i=1}^{N} w_i} \qquad (2)$$

where N is the number of estimated locations, d_i is the Euclidean distance from the ith estimated location to the final estimated location, and w_i is a series of weighting factors.

[00131] As discussed above, when subsets of available NMRs are considered, however, the estimated locations may also differ. Therefore, an exemplary confidence measure may also be defined upon an estimated location given by any function that increases as the number of subset locations agree with the final estimated location. A non-limiting example of such a function may be the fraction of total locations that agree with the final estimated location or the fraction of total locations that lie within a certain distance of the final estimated location. In a further embodiment, weights may be assigned to the location estimates by utilizing the parameters or functions employed in determining the estimated location to thereby weight the determination of the associated confidence measure. Further exemplary confidence measures may be a function of pdfs, distortion measures, Mahalanobis distances, etc. with respect to any one or sets of NUGs.

[00132] Exemplary weighting quantities, *e.g.,* distortion measures, pdfs, etc., may also be derived while estimating any location from single and multiple NMRs or their subsets, and may also be utilized to estimate location error. Empirically, the magnitudes of these weighting quantities may be correlated with the expected error. This relationship may be established graphically or in tabular format as a function of environmental characteristics (*e.g.,* urban, suburban, seasonal, etc.). As a result, given a set of weighting quantities, an associated error may be predicted for a specific location estimate.

[00133] In one embodiment of the present subject matter, if the set of derived locations utilizing a set and/or subset of NMRs exhibit clusters, cluster separation may be employed between the highest aggregate weighted clusters to define an expected error. Such a distance may be termed as an inverse confidence measure as the larger the distance becomes, the greater the chance of error in the final location estimate if the corresponding cluster were selected. It follows that if the aggregate weight for a distant cluster is small, this distance should be modified to de-weight the associated distance by the weight of the cluster. An exemplary determination may multiply the cluster distance by a ratio of the weight of a selected cluster to the weight of a distant cluster; however,

many such variations of this fundamental idea are clearly conceivable and such an example should not limit the scope of the claims appended herewith.

[00134] In another embodiment of the present subject matter, when each of the individual location estimates are generally at the same location (*e.g.,* each located at the same calibration or grid point) the resulting error estimate would be zero or near zero. In such a scenario, the error estimate may be bounded by a minimum error value such as, but not limited to, a configurable constant based upon the overall expected system accuracy (*e.g.,* the 25th percentile of overall system error, etc.).

[00135] It should be noted that the statistical averaged or weighted averaged location accuracy improves as the number of individual location estimates averaged or determined increases. For example, a final location estimate that comprises the average of two individual locations may generally be less accurate than a final location estimate comprising an average of twenty individual location estimates. Further, the optimal number of location estimates to combine or consider is dependent upon several factors including, but not limited to, the speed of the mobile device, the rate of acquiring NMRs, etc. This relationship may also be utilized to improve the error estimate as the number of individual location estimates increases.

[00136] In embodiments of the present subject matter wherein any one or multiple individual location estimates are "fall back" locations (*e.g.,* default locations that may be based upon serving cell identification location), a default error estimate may be determined based upon an expected statistical accuracy of cell identification location. This determination may be a function of cell site geometry in an associated or corresponding operating market and may also be determined empirically through accuracy testing. Exemplary scenarios in which default locations may be encountered include, but are not limited to, when the NMR does not contain any NC measurements, when the available set of NMRs for the mobile device location generates a set of candidate locations that does not cluster (*e.g.,* when the individual location estimates

appear to be randomly distributed over a geographic region), when an NMR has very few reporting NCs and the confidence measure is poor, and combinations thereof.

[00137] In embodiments of the present subject matter where NMR data may be missing or invalid, the coordinates of the cell serving a mobile device may be retrieved from a respective site database from the serving cell identifier. In this instance, an exemplary default location may be a location that is a configurable distance away from the serving site. The configurable distance may or may not be positioned at a heading along the serving sector azimuth. For air standards in which certain parameters (*e.g.,* timing advance, round trip timing, etc.) are available, this data may also be converted to an approximate range estimate from the serving site and utilized with other applicable parameters. For example, when such parameters are available, the default location may be enhanced by selecting a location on the serving cell azimuth at a distance from the site given by a TA range estimate.

[00138] In embodiments of the present subject matter where an NMR may include Time Difference of Arrival ("TDOA") data, this parameter may be utilized to derive a region within the cell to constrain the default location. For example, the TDOA, assuming the base station time offsets are known, defines a hyperbola in the region of interest. An intersection of this hyperbola with the applicable TA region to this cell may be utilized as a default location estimate. Alternatively, a default location estimate may be employed that does not rely on a serving sector heading if there exists a priori knowledge of sector coverage density. For example, if a sector coverage region can be determined (*e.g.,* through drive testing, etc.), then the centroid of the sector coverage region may be stored in the respective site database by sector for each site and retrieved as a default location.

[00139] A further aspect of embodiments of the present subject matter may also improve location accuracy by interpolating between grid point locations when more than one grid point matches the calibration or reported data within a predetermined value.

Generally, grid-based signal strength pattern matching location systems determine a quantitative measure of how close each candidate grid point (*e.g.*, NUG or UG) matches mobile device reported measurement parameters. The location estimate of the mobile device may be given by the grid point having a match within a predetermined range. Further, as the actual location of the mobile device is generally not constrained to lie at a grid point location, interpolation between grid points may result in a more accurate location estimate.

[00140] During an exemplary interpolation according to one embodiment of the present subject matter, an analysis of whether interpolation should be performed may be determined as well as a selection of the appropriate grid or calibration points for the interpolation. Distance metrics may also be determined on any number of grid points. Exemplary metrics are discussed above and may include, but are not limited to, pdfs, Mahalanobis distance between parameter vectors, ordering number between ordered NCs in the NMR, NUG, UG, and combinations thereof. By way of a non-limiting example, it may be assumed that the distance metric for each of N candidate grid points (N > 1) is determined and sorted. Representing the distance metric as C, then for each ith candidate, i = 1...N, an appropriate metric may be determined by the following relationship:

$$C\_Ratio_i = [C_i - C_{\min}]/[C_N - C_{\min}] \qquad (3)$$

where C_i is a metric associated with an ith candidate grid point, C_N is a metric associated with the worst corresponding candidate grid point, and C_{min} is a metric associated with the best corresponding candidate grid point. It follows that grid points having a C_{ratio} less than a predetermined and configurable threshold value may be a candidate for interpolation.

[00141] Generally, interpolation occurs between adjacent or nearby grid points. To minimize or prevent interpolation across widely spaced grid points, the distance from

each interpolation candidate grid point to the minimum cost grid point may be less than a configurable distance threshold.

[00142] In embodiments when there are few grid point candidates or when there are fewer than a configurable number of candidate grid points, an appropriate metric may be determined by the following relationship:

$$C\_Ratio_i = [C_i - C_{\min}]/[C_{\min}] \qquad (4)$$

where C_i is a metric associated with an ith grid point and C_{min} is a metric associated with the best corresponding grid point. Equation (4) may thus enable an identification of appropriate grid points for interpolation when N is small. Equation (4) may also be performed to prevent interpolation between widely separated grid points.

[00143] Once the grid points for interpolation have been identified, one embodiment of the present subject matter may employ weighted averaging to determine a final interpolated location. An exemplary weight assigned to the ith grid point in computing the final interpolated location may be determined by the following relationship:

$$Wi = \frac{\frac{1}{Ci}}{\sum_{i=1}^{N}\left(\frac{1}{Ci}\right)} \qquad (5)$$

where C_i is a metric associated with an ith grid point. Weighted averaging may also be utilized rather than uniform weighting to ensure that the best matching grid point (*i.e.,* minimum cost grid point) exerts a larger influence on the final location estimate.

[00144] As discussed above, each grid point (NUG or UG) may provide one or a plurality of parameters and/or functions characterizing the grid point. Given a received set of one or more NMRs obtained at an unknown location, an accurate estimation of the unknown location may be determined using a characterization of the grid points over a

geographic region. In one embodiment of the present subject matter, a distortion measure may be determined between available NMRs and grid point characteristics to assist in the estimation.

[00145] Generally, embodiments of the present subject matter may utilize any number of methods to determine a distortion measure, *e.g.*, a mismatch distance between mobile reported measurements and a candidate grid point's stored measurement data. The associated "cost" value may also be inversely proportional to an increasing function of the probability that the mobile device is located at or in the vicinity of a grid point.

[00146] In one embodiment of the present subject matter, a distortion measure may comprise a combination of the values of each parameter in an NMR and each corresponding parameter in the grid point (NUG or UG) characteristics. The distortion measure may generally increase as the mismatch between any of the parameters increases and vice versa. For example, an exemplary cost value may be determined utilizing a Mahalanobis distance provided by the following relationship:

$$COST = \alpha(TA_{rpt} - TA_{cand})^2 + \sum_i \left[\left(\frac{RxLevDiff(i)^2}{MAXDIFF^2} \right) NCCU \right] \qquad (6)$$

where α is 0 or 1 which controls whether TA differences are included in the determination (*e.g.*, 1 for GSM and 0 for iDEN), TA_{rpt} is the TA for the NMR, TA_{cand} is the TA for the candidate grid point in the calibration database and/or a representative value, *RxLevDiff(i)* represents the difference in RxLev (received signal strength) for the ith neighbor cell or serving cell, *I* is an index to neighbor or serving cells (*e.g.*, if only NC received signal strengths are used and there are six reporting NCs, then $i = 1$ to 6; if in addition, a serving cell signal strength is included then $i = 1$ to 7), *NCCU* represents an NC cost unit where an increasing *NCCU* increases the cost penalty for RxLev difference relative to the cost penalty for TA difference, and *MAXDIFF* is a configurable parameter that limits the cost incurred for differences in signal strengths. *MAXDIFF* may be set to

20dB or another configurable value. RxLev differences exceeding *MAXDIFF* would not incur an additional cost penalty.

[00147] Embodiments of the present subject matter may determine *RxLevDiff(i)* through any number of methods including, but not limited to, the following relationships:

$$RxLevDiff(i) = (RxLevServ - RxLevNeigh(i))_{NMR} - (RxLevServ - RxLevNeigh(i))_{CND} \quad (7)$$

for $i = 1{:}6$;

$$RxLevDiff(i) = (RxLevNeigh(i))_{NMR} - (RxLevNeigh(i))_{CND} \quad (8)$$

for $i = 1{:}6$;

$$RxLevDiff(i) = (RxLevNeigh(1) - RxLevNeigh(i))_{NMR} - (RxLevNeigh(1) - RxLevNeigh(i))_{CND} \quad (9)$$

for $i = 2{:}6$;

$$RxLevDiff(i) = (AvgRxLevNeigh - RxLevNeigh(i))_{NMR} - (AvgRxLevNeigh - RxLevNeigh(i))_{CND} \quad (10)$$

for $i = 1{:}6$;

$$RxLevDiff(i) = (AvgRxLev - RxLev(i))_{NMR} - (AvgRxLev - RxLev(i))_{CND} \quad (11)$$

for $i = 1{:}7$.

[00148] With reference to the above relationships, Equation (7) provides a comparison between the signal strengths of the serving cell and the ith NC between NMR and candidate points, Equation (8) provides a comparison between the signal strengths of the ith NC between NMR and candidate points, Equation (9) provides a comparison between the signal strengths of a first common NC and the ith NC between NMR and candidate points, Equation (10) provides a comparison between the average signal strengths of the NCs and the signal strengths of the ith NC between NMR and candidate

points, and Equation (11) provides a comparison of the average signal strengths of the serving cells and NCs and the signal strengths of the ith serving cell and NC between NMR and candidate points.

[00149] In a further aspect of embodiments of the present subject matter, an estimated location may be generated for a mobile device given a received NMR and a region "R" over which a set "S" of grid points (NUGs or UGs) have been established. As described above, each grid point may include a series of parameters, components and/or functions characterizing the respective grid point. Provided a received set of one or more NMRs obtained at some unknown location, an estimation of that unknown location may be determined as a function of a characterization of the grid points over this region R.

[00150] In one embodiment of the present subject matter, an estimated location of a mobile device may be determined using any single NMR (drawn from a set or subset of NMRs) by any number of the following methods or combinations thereof. For example, one embodiment may match an ordered list of NCs, where the ordering may be in terms of any one of a number of parameters characterizing the NMR, such as, for example, NC power level, in a respective NMR to a similarly ordered list of NCs in the grid point(s) (NUG or UG) and (a) generate the estimated location as the centroid of the best cluster of matching grid points, (b) generate the estimated location as the location of the highest joint probability matching grid point, (c) generate the estimated location as the (joint probability) weighted sum of the locations of a set of matching grid points, (d) generate the estimated location as the (joint probability) weighted sum of the clustered locations of a set of matching grid points (*i.e.,* cluster the locations of the matching grid points and then apply a cumulative probability for all contained grid points in a cluster as weight for the respective cluster), (e) generate the estimated location by combining locations derived from NMR subsets, or any combination thereof.

[00151] In an additional embodiment, if the ordered list of NCs in the NMR (ordered with respect to the magnitude of any particular parameter characterizing the

NMR) does not provide an exact match to the ordered list of NCs that may be available as a characteristic of a grid point, the method may evaluate those grid points (NUGs or UGs) including an ordered list thereof that may contain an ordered list in the NMR. Thus, the ordered list in the NMR may form a subset of the ordered list in the grid point, and the method may (a) generate an estimated location as the centroid of the best cluster of matching grid points, (b) generate the estimated location as the location of the highest joint probability matching grid point, (c) generate the estimated location as the (joint probability) weighted sum of the locations of a set of matching grid points, (d) generate the estimated location as the (joint probability) weighted sum of the clustered locations of a set of matching grid points, (e) generate the estimated location by combining locations derived from NMR subsets, or any combination thereof.

[00152] In embodiments of the present subject matter where the ordered list of NCs in the NMR is not contained in the ordered list of NCs for any grid point, then the method may utilize the highest power subset of NCs in the NMR (*e.g.*, ordered from highest to lowest power) that provides either an exact match or is contained in the ordered list of NCs in the grid point. The method may then (a) generate an estimated location as the centroid of the best cluster of matching grid points, (b) generate the estimated location as the location of the highest joint probability matching grid point, (c) generate the estimated location as the (joint probability) weighted sum of the locations of a set of matching grid points, (d) generate the estimated location as the (joint probability) weighted sum of the clustered locations of a set of matching grid points, (e) generate the estimated location by combining locations derived from NMR subsets, or any combination thereof.

[00153] In a further embodiment of the present subject matter, the individual pdf of each NC power level or other parameter in the NMR over the set of available grid points (NUGs or UGs) may be evaluated. A joint probability may then be determined as the product of such marginal probabilities and an estimated location generated as (a) the location of the highest joint probability matching grid point, (b) the (joint probability)

weighted sum of the locations of a set of matching grid points, (c) the (joint probability) weighted sum of the clustered locations of a set of matching grid points, (d) a combination of locations derived from NMR subsets, or any combination thereof.

[00154] In one embodiment, the joint probability of the NMR NC power levels or other parameters may be evaluated over the set of available grid points. The method may then generate an estimated location as (a) the location of the highest joint probability matching grid point, (b) the (joint probability) weighted sum of the locations of a set of matching grid points, (c) the (joint probability) weighted sum of the clustered locations of a set of matching grid points, (d) a combination of locations derived from NMR subsets, or any combination thereof.

[00155] In another embodiment, a distortion measure may be determined between the grid point measured parameters (*e.g.,* mean NC power level, TA value, RTT value, etc.) and corresponding parameters in the NMR. Exemplary distortion measures have been provided above and may be, but are not limited to, a Mahalanobis distance, etc. Any weighting in this distance over dissimilar parameters may also be optimized empirically or determined by calculation. Utilizing an exemplary distortion measure, the method may generate an estimated location as (a) the location of the grid point with a least distortion measure, (b) the weighted sum of the locations of the set of grid points (weights may also be applied as a function of the distortion measure), (c) the weighted sum of any one or multiple clustered locations of a set of grid points, (d) a combination of locations derived from NMR subsets (where the measure set M is the distortion measure).

[00156] In yet another embodiment, an estimated location may be selected by matching the NC power level or other parameter ordering in the NMR to the NC power or other parameter ordering in the grid points (NUG or UG) and utilize an ordering number evaluation. An exemplary ordering number may be an indicator regarding the number of relative shifts in position occurring between the NMR and the grid point(s) NC ordered power levels or other parameters. By way of a non-limiting example, in an NMR

the NC power levels may be ordered as ABCDE whereas the selected grid point may provide an ordering of BACDE. This results in an ordering number of 1 (a single shift). Multiple variations of the ordering number may be considered and determined, however, these variations may be a measure of the distortion in ordering between the NC power levels evident in the grid point as compared to the NC parameters seen in the NMR. An aggregate ordering number for a set of NMRs may then be obtained by combining the ordering numbers for each individual NMR. A final estimated location may be a grid point cluster having the smallest ordering number. In a further embodiment, the ordering number or ordering of an exemplary characteristic may also be regarded as a distortion measure such that the method may generate an estimated location as (a) the location of the grid point with a least distortion measure, (b) the weighted sum of the locations of the set of grid points (weights may also be applied as a function of the distortion measure), (c) the weighted sum of any one or multiple clustered locations of a set of grid points, (d) a combination of locations derived from NMR subsets (where the measure set M is the distortion measure).

[00157] With respect to any of the various methods described above, embodiments of the present subject matter may also filter parameters prior to generating an estimated location. For example, an embodiment may match the serving cell/sector of candidate grid points to the serving cell/sector of the NMR and then proceed with any of the methods previously described. A further embodiment may also filter candidate grid points using other available parameters (*e.g.,* TA, RTT, etc.) for the NMR and then proceed with any of the methods previously described. This exemplary filtering may also be set wider than the actual parameter (TA, RTT, etc.) determined value by a configurable threshold.

[00158] Candidate grid points may also be filtered by utilizing a mobile orientation parameter (*e.g.,* indoors, outdoors, facing North or South, titled upwards, azimuth and elevation, etc.) applied during construction of the grid points, by utilizing those grid points where the serving cell identifier and serving control channel agrees with the NMR

data, by utilizing the magnitude of the serving cell forward link control channel received signal level (and applying a configurable tolerance to this parameter), by eliminating those grid points not having at least *N* (configurable) NC received signal levels in common with the NMR, or any combination thereof and then proceeding with any of the methods previously described.

[00159] In embodiments of the present subject matter where a set of NMRs obtained at some unknown location (or locations in close proximity to each other) may be available, the aforementioned methods may be expanded to exploit the multiplicity of information. For example, an estimated location may be generated for each NMR in a set of NMRs by any or all of the methods applicable to a single NMR as indicated above and a tightest cluster of a single NMR location may be determined. Such a determination may also utilize a metric derived while locating that NMR (*e.g.*, joint probability, Mahalanobis distance, etc.) to weight the clusters.

[00160] In another example, a representative NMR may be generated from a set of NMRs and any or all of the methods applicable to a single NMR as indicated above may be applied thereto. The representative NMR may be generated by obtaining a representative value for each of the NCs seen in the respective set of NMRs, and similarly obtaining a representative value for each of the other parameters seen in the NMRs. In another embodiment, these representative values may be obtained as a function of the available set of values, *e.g.,* for NC power level mean or median power may be utilized.

[00161] In a further example, transitions in any of the parameters within the set of NMRs may be observed. Transitions may be utilized in reducing the applicable region for an estimated location. As many parameters represent a range of location possibilities, when a parameter changes, it may be inferred that the region of interest is at a boundary of the ranges represented by the parameter prior to and after the change. Therefore, any one of these boundaries determined for any parameter change within the applicable set

may reduce the candidate region for the mobile device location. Exemplary parameter changes may be, but are not limited to, changes in signal power levels with respect to a particular NC, rate or pattern of dropping in and out of a particular NC signal, changes in serving cell or sector, changes in TA, RTT or equivalent parameter, and combinations thereof.

[00162] Additional embodiments may determine a distortion measure between the grid point characteristics or measured parameters and corresponding parameters of all NMRs taken collectively without reduction to representative values. Any weighting in this measure over dissimilar parameters may be optimized empirically. Utilizing a distortion measure, exemplary methods may generate an estimated location as (a) the location of the grid point having the least distortion measure, (b) the weighted sum of the locations of a set of grid points (any weights applied may also be a function of the distortion measure), (c) the weighted sum of clustered locations of a set of grid points, (d) as a combination of locations derived from NMR subsets (where the measure set M is now the distortion measure).

[00163] Further embodiments may match a variety of parameters and functions generated and stored describing a grid point (*i.e.,* the grid point characteristics) with similar parameters and functions determined for the set of NMRs by utilizing a distortion measure to evaluate the similarity therebetween. Exemplary parameters and functions may be, but are not limited to, the following: (a) an ordered list of neighboring cells; (b) functions defined on the absolute neighboring cell power levels (e.g., mean, median, k^{th} moment, cluster-mean, etc.); (c) functions defined on the relative neighboring cell power differences (e.g., mean, median, k^{th} moment, cluster-mean, etc.); (d) serving cell/sector; (e) timing advance parameter (or equivalent); (f) individual pdf (probability density function or probability distribution function) of each neighboring cell power level; (g) joint pdf of neighboring cell power levels; (h) mean and variance of neighboring cell power levels; (i) mobile device orientation (e.g., indoors, outdoors, direction mobile device is facing (e.g., North, South, etc.), tilted upwards, azimuth, elevation, etc.); (j) a

compact and/or efficient representation that enables retrieval of the calibration data NMR vectors assigned to this grid point; (k) the network state as indicated in the calibration data; (l) a confidence measure indicative of the reliability of the calibration data feeding this grid point; and (m) any combinations of the above. In this exemplary method, further embodiments may also construct a pdf for the set of NMRs and determine a similarity to the pdf for a grid point by a measure applicable to pdfs such as, but not limited to, the Bhattacharya distance, Kullback-Liebler divergence or other measures for probability distributions. Having generated such measures with respect to the set of candidate grid points the method may generate an estimated location as (a) the location of the grid point with the least distortion measure, (b) the weighted sum of the locations of a set of grid points (any weights applied as a function of the distortion measure), (c) the weighted sum of clustered locations of a set of grid points, (d) a combination of locations derived from NMR subsets (where the measure set M is the distortion measure).

[00164] One aspect of the present subject matter may generate a location estimate of a mobile device through methods of intersections using any single NMR or set of NMRs. Utilizing a single NMR, an exemplary intersection method may generate an estimated location based upon an observation that the region of validity for any one of the parameters in a particular NMR may define a region where the estimated location of a mobile device should exist. By way of a non-limiting example, the power level or other parameter of a particular NC (*e.g.,* NC1) in an NMR having a power level of P dBm may be evaluated. With regard to the calibration data such that for every NMR in a respective set of calibration data, the particular NC power level may be within +/- x dBm of P. As discussed above, every calibration data vector provides an associated location, and the location of each such data vector in a respective calibration data subset may form a representative region, *R1*, defining a region within a location space having a power constraint upon NC1. *R1* may or may not be contiguous, and may even be empty. In the event that *R1* is empty, then the value of x may be increased by a predetermined value (or iteratively increased) until a nonempty region emerges and comprises valid calibration

data points satisfying (*e.g.,* falling into the range of) the obtained NMR power or parameter requirement. This may then define a region formed of discrete points in two dimensional location space. Similar regions may be constructed for each of the NCs and for each of the parameters or functions in the NMR. It follows that a range array may thus be generated containing range that define maximum and minimum values for each parameter of the form of two aggregated vectors.

[00165] An intersection of the aforementioned regions may then be determined. If a non-empty intersection occurs, the range array may be modified to approach the actual NMR data vector. Any such modification may be attempted in each NC power level or other NMR parameter level individually. In this method, the intersection region may be reduced until the smallest (and possibly clustered) intersection occurs. An estimated location for a mobile device may then be determined as the centroid of this intersection or may be determined through an evaluation of the pdf or other exemplary statistical measure for the calibration data within the intersection or a selected region. Further, an estimated location may also be determined utilizing any one or combination of the methods described above with reference to the generation of a location estimate utilizing any single NMR or set of NMRs. If, however, the intersection is empty, the range array may be modified to be wider than the actual NMR vector until a feasible solution can be found. If no solution is found with the respective range array at a higher threshold, a subset of the NCs in the NMR may be evaluated (*e.g.,* by dropping the lowest power NC in the NMR, etc.) and the entire process described above may then be employed.

[00166] A distortion measure may also be determined along with a respective range array that generates a finite intersection region. The applicable distortion measure may be determined as, but not limited to, the largest width of any NMR NC power level or parameter level in the range array, a weighted combination of the individual widths of the NMR NC power or parameter levels in the range array, the area of the final intersection region, or any combination thereof. This distortion measure can then be an indicator of the quality or expected accuracy of the eventual location estimate.

[00167] Additionally, any subsets of the NMR(s) may be examined for intersection regions. If multiple disjoint regions occur with different NMR subsets, these disjointed regions may be regarded as a set of grid points (NUGs or UGs) and evaluated for an estimated location employing any one or combination of the methods described above with reference to the generation of a location estimate utilizing a single NMR or set of NMRs. By way of a non-limiting example, a pdf may be generated for each disjointed region, and then the techniques of location estimation described above utilizing any single NMR or set of NMRs may be employed to determine which of the regions may be the best location estimate.

[00168] Utilizing a set of NMRs, an exemplary intersection method may generate an estimated location for each NMR in the set of NMRs by any or all of the methods applicable to a single NMR as discussed in the previous paragraphs and (a) determine the tightest cluster of such single NMR locations (optionally using a metric derived while locating that NMR to weight the clusters such as a distortion measure (*e.g.*, joint probability, Mahalanobis distance, cluster radius, etc.)), (b) if multiple disjoint regions occur for one or more NMRs, use the methods described above with reference to the generation of a location estimate utilizing any single NMR or set of NMRs to determine the most likely estimate for the location estimate, and/or (c) if multiple disjoint regions occur for some NMRs but not for others, utilizing regions having an appropriate weighting and/or utilizing a distortion measure and any additional weighting that may allocate a greater likelihood to those NMRs generating a non-disjoint region.

[00169] Utilizing a set of NMRs, an exemplary intersection method may also generate a representative NMR from the set of NMRs and apply the methods described above with regard to a single NMR to the representative NMR. The representative NMR may be generated by determining a representative value for each of the NCs available in the set of NMRs and determining a representative value for each of the other parameters available in the respective NMRs. Exemplary representative values may be obtained as a function of the available set of values (*e.g.*, for NC power, mean or median). In the

alternative, this exemplary method may also consider a set of NC power or parameter levels (applicable to each NMR NC level) when viewed over the set of NMRs and select that NC level requiring the narrowest range to provide a valid region. This power or parameter level may be the applicable level in the representative NMR. It should be noted that embodiments of the present subject matter employing this exemplary method may produce results different from the aforementioned grid point approach as calibration data too few in number to effectively emerge in a pdf of the grid point(s) to which the data are applied may, however, emerge in this exemplary method.

[00170] It is also another aspect of embodiments of the present subject matter to generate a location estimate for a mobile device utilizing multiple constructions of characterizing information from grid points (NUGs or UGs) over the same region. By way of a non-limiting example, an exemplary method may utilize multiple sets of grid points constructed on the same calibration data (or over several such sests of calibration data) and select a set of grid points such that, when evaluated over the methods described above regarding single NMRs or sets of NMRs, representative NMRs, etc., provides the best criteria of fit. Exemplary criteria may be, but are not limited to total probability, cluster radius, Euclidean norm, Mahalanobis distance or other exemplary parameters that are an indicator of a "goodness" of fit. The estimated location within the grid point construction providing the best criteria of fit may be determined as the final location estimate for a respective mobile device.

[00171] In a further embodiment of the present subject matter, clustering of data vectors may also occur in another dimension of construction space (rather than occurring purely in the location space). Therefore, if a particular location exists in the best cluster over multiple grid point constructions, that location may be determined as the correct location for the estimate. The estimated location may then be obtained by applying the methods described above regarding single NMRs or sets of NMRs, representative NMRs, etc. within selected grid point set (NUG or UG) or over all grid point sets. It follows that each construction method may also be visualized as a layer in three dimensional space

having a separate set of candidate locations or clusters (associated weights may also be applied thereupon). Exemplary weights may be, but are not limited to, distortion measures, probabilities, etc. In a further embodiment of the present subject matter, a vertical combination of candidate locations across the various constructions forming the third dimension may also be employed; thus, clustering in this instance may be a process that, when viewed in each location space (which is two dimensional) and in the vertical dimension, examines each or combinations of different constructions. An acceptable location estimate may generally be expected to cluster well in both location space and construction space, and the tightness of this cluster may then be employed as an additional confidence measure upon the respective location estimate and utilized in the methods described above.

[00172] Figure 29 is a flow chart for a method for locating a mobile device according to one embodiment of the present subject matter. With reference to Figure 29, at block 2910, a plurality of calibration or grid points may be provided in a geographic region. At block 2920, a plurality of NMRs may be provided for a mobile device in the geographic region. Ones of the plurality of grid points may be compared to one or more parameters of ones of the plurality of NMRs in block 2930. In another embodiment of the present subject matter, the comparison may further comprise generating a distortion measure that is a function of a combination of parameters of ones of the plurality of network measurement reports and corresponding parameters of ones of the plurality of grid points. An exemplary distortion measure may be, but is not limited to, a Mahalanobis distance, a comparison of received signal strengths of a serving cell and a neighboring cell between ones of the plurality of NMRs and grid points, a comparison of received signal strengths of a neighboring cell between ones of the plurality of NMRs and grid points, a comparison of received signal strengths of a first common neighboring cell and another neighboring cell between ones of the plurality of NMRs and grid points, a comparison of average received signal strengths of reporting neighboring cells and received signal strengths of a neighboring cell between ones of the plurality of NMRs and

grid points, a comparison of average received signal strengths of serving and reporting neighbor cells received signal strengths of a selected neighbor or serving cell between ones of the plurality of NMRs and grid points, and any combination thereof. A first location estimate of the mobile device may be generated for each of the ones of the plurality of NMRs in block 2940, and in block 2950, a second location estimate of the mobile device may be determined as a function of at least one of the generated first location estimates.

[00173] Figure 30 is a flow chart for a method for locating a mobile device according to one embodiment of the present subject matter including identifying and omitting outlier first location estimates. With reference to Figure 30, blocks 3010, 3020, 3030, 3040 and 3050 are similar to blocks 2910, 2920, 2930, 2940 and 2950, respectively. At block 3060, the method may further determine a Mahalanobis distance from each first location estimate to the second location estimate and at block 3070, determine a distance threshold from a median of the determined Mahalanobis distances multiplied by a predetermined factor. At block 3080, a third location estimate may then be determined by averaging two or more of the first location estimates. In such a determination the first location estimates having a Mahalanobis distance to the second location estimate greater than a predetermined distance threshold may be omitted from the third location estimate determination.

[00174] Figure 31 is a flow chart for a method for locating a mobile device according to another embodiment of the present subject matter. With reference to Figure 31, blocks 3110, 3120, 3130, 3140 and 3150 are similar to blocks 2910, 2920, 2930, 2940 and 2950, respectively. At block 3151, the determination of a second location estimate may further comprise averaging two or more first location estimates, or at block 3152, the determination of a second location estimate may further comprise employing a weighted averaging of ones of the first location estimates. At block 3153, the determination of a second location estimate may further comprise weighting a first location estimate by an inverse of a distance metric, or at block 3154, the determination of a second location

estimate may further comprise normalizing a first location estimate by a sum of an inverse of a distance metric. Further, at block 3155, the determination of a second location estimate may further comprise weighting a first location estimate as a function of the number of reporting neighboring cells to a serving cell serving the mobile device.

[00175] Figure 32 is a flow chart for a method for locating a mobile device according to one embodiment of the present subject matter including omitting a first location estimate. With reference to Figure 32, blocks 3210, 3220, 3230, 3240 and 3250 are similar to blocks 2910, 2920, 2930, 2940 and 2950, respectively. At block 3260, the method may further omit a first location estimate having an error greater than a predetermined threshold.

[00176] Figure 33 is a flow chart for a method for locating a mobile device according to one embodiment of the present subject matter including interpolating between grid points. With reference to Figure 33, blocks 3310, 3320, 3330, 3340 and 3350 are similar to blocks 2910, 2920, 2930, 2940 and 2950, respectively. At block 3360, the method may further interpolate between ones of the plurality of grid points when more than one grid point corresponds to a parameter of the plurality of NMRs.

[00177] Figure 34 is a flow chart for a method for locating a mobile device according to another embodiment of the present subject matter including interpolating between grid points and/or assigning weights to selected grid points. With reference to Figure 34, blocks 3410, 3420, 3430, 3440, 3450 and 3460 are similar to blocks 3310, 3320, 3330, 3340, 3350 and 3360, respectively. At block 3461, the interpolation may be a function of the relationship provided in Equation (3) above. With reference to Equation (3), a grid point having a C_Ratio_i less than a predetermined threshold may be a candidate grid point for the interpolation in one embodiment and/or a grid point having a distance from the best corresponding grid point less than a predetermined threshold may be a candidate grid point for the interpolation. At block 3462, the interpolation may also be a function of the relationship provided in Equation (4) above. At block 3470, the

method may further assign weights to an ith grid point as a function of the relationship provided in Equation (5) above.

[00178] Figure 35 is a flow chart for a method for locating a mobile device according to another embodiment of the present subject matter including providing a default location. With reference to Figure 35, blocks 3510, 3520, 3530, 3540, and 3550 are similar to blocks 2910, 2920, 2930, 2940 and 2950, respectively. At block 3560, the method may further comprise providing a default location for the second location estimate if a second location estimate cannot be determined as a function of at least one of the generated first location estimates. In one embodiment at block 3561, the default location may be a predetermined distance from a serving cell serving the mobile device at a heading along a serving sector azimuth. In another embodiment at block 3562, the default location may be a function of timing advance or round trip time and/or may be an approximate range estimate from a serving cell serving the mobile device. In an additional embodiment in block 3563, the default location may be a region determined as a function of a TDOA measurement and/or where the region is the intersection of a hyperbola defined by said TDOA with a timing advance region applicable to a serving cell serving the mobile device. In yet a further embodiment in block 3564, the default location may be determined as a function of a priori knowledge of sector coverage density.

[00179] Figure 36 is a flow chart for a method of improving a location estimate of a mobile device. With reference to Figure 36, at block 3610, a plurality of grid points in a geographic region may be provided and at block 3620, a set of NMRs for a mobile device in the geographic region may be provided. The set of NMRs may or may not include one or more subsets of NMRs. At block 3630, ones of the plurality of grid points may be compared to at least one parameter of a subset of the NMRs, and at block 3640, a first location estimate of the mobile device may be generated for each subset of NMRs. A second location estimate of the mobile device may be determined as a function of at least one of the generated first location estimates at block 3650, and at block 3660, an attribute

of the second location estimate may be indicated as a function of a parameter of a subset of the NMRs. In additional embodiments, the attribute may be determined as a function of any one or combination of a fraction of first location estimates corresponding with the second location estimate and a fraction of total first location estimates that lie within a predetermined distance of the second location estimate.

[00180] Figure 37 is a flow chart for a method of improving a location estimate of a mobile device according to another embodiment of the present subject matter. With reference to Figure 37, blocks 3710, 3720, 3730, 3740, 3750 and 3760 are similar to blocks 3610, 3620, 3630, 3640, 3650 and 3660, respectively. At block 3751, the determination of a second location estimate may further comprise clustering the set of NMRs without reference to parameters in any of the subsets of NMRs. At block 3752, the second location estimate may be determined as the centroid of a region containing the tightest cluster of NMRs in the set of NMRs. The cluster may or may not possess an aggregate measure higher than a predetermined threshold. At block 3753, the second location estimate may be determined as the centroid of ones of the plurality of grid points occurring most often in the set of NMRs. At block 3754, the determination of a second location estimate may further comprise clustering a subset of NMRs as a function of power of neighboring cells. At block 3755, the determination of a second location estimate may further comprise clustering a subset of NMRs as a function of power of neighboring cells and another parameter in the subset. At block 3756, the determination of a second location estimate may further comprise averaging two or more first location estimates. At block 3757, the determination of a second location estimate may also further comprise employing a weighted averaging of ones of the first location estimates. In another embodiment, at block 3758, the determination of a second location estimate may further comprise weighting a first location estimate by an inverse of a distance metric. At block 3759, the determination of a second location estimate may also comprise normalizing a first location estimate by a sum of an inverse of a distance metric, and at block 3761, the determination of a second location estimate may further comprise

weighting a first location estimate as a function of the number of reporting neighboring cells to a serving cell serving the mobile device. In another embodiment at block 3762, the determination of a second location estimate may further comprise weighting a first location estimate as a function of the indicated attribute. Exemplary weighting may be, but is not limited to, a Mahalanobis distance, a probability density function.

[00181] Figure 38 is a flow chart for a method of improving a location estimate of a mobile device according to another embodiment of the present subject matter including omitting a first location estimate. With reference to Figure 38, blocks 3810, 3820, 3830, 3840, 3850 and 3860 are similar to blocks 3610, 3620, 3630, 3640, 3650 and 3660, respectively. At block 3870, the method may further omit a first location estimate having an error greater than a predetermined threshold.

[00182] Figure 39 is a flow chart for a method for locating a mobile device according to one embodiment of the present subject matter including identifying and omitting outlier first location estimates. With reference to Figure 39, blocks 3910, 3920, 3930, 3940, 3950 and 3960 are similar to blocks 3610, 3620, 3630, 3640, 3650 and 3660 respectively. At block 3970, the method may further determine a Mahalanobis distance from each first location estimate to the second location estimate and at block 3980, determine a distance threshold from a median of the determined Mahalanobis distances multiplied by a predetermined factor. At block 3990, a third location estimate may then be determined by averaging two or more of the first location estimates. In such a determination the first location estimates having a Mahalanobis distance to the second location estimate greater than a predetermined distance threshold may be omitted from the third location estimate determination.

[00183] Figure 40 is a flow chart for a method of improving a location estimate of a mobile device according to a further embodiment of the present subject matter. With reference to Figure 40, blocks 4010, 4020, 4030, 4040, 4050 and 4060 are similar to blocks 3610, 3620, 3630, 3640, 3650 and 3660, respectively. At block 4061, the

indication of an attribute of the second location estimate may further comprise determining an error estimate as an average of distances from each first location estimate to the second location estimate. In one embodiment at block 4062, the error estimate may be determined as a function of the relationship provided in Equation (1) above. In a further embodiment at block 4063, the error estimate may be determined as a function of the relationship provided in Equation (2) above. With reference to Equation (2), exemplary weighting factors may be, but are not limited to probabilities determined during the first location estimate generation, probabilities determined during the second location estimate determination, distortion function values determined during the first location estimate generation, distortion function values determined during the second location estimate determination, and combinations thereof. In yet another embodiment in block 4064, the error estimate may be determined as a function of subset NMR cluster separation between a highest aggregate weighted cluster.

[00184] Figure 41 is a flow chart for a method of improving a location estimate of a mobile device according to a further embodiment of the present subject matter including providing a default location. With reference to Figure 41, blocks 4110, 4120, 4130, 4140, 4150 and 4160 are similar to blocks 3610, 3620, 3630, 3640, 3650 and 3660, respectively. At block 4170, a default location may be provided for the second location estimate if the attribute is less than a predetermined threshold. In one embodiment at block 4171, the default location may be a predetermined distance from a serving cell serving the mobile device at a heading along a serving sector azimuth. In another embodiment at block 4172, the default location may be a function of timing advance or round trip time and/or may be an approximate range estimate from a serving cell serving the mobile device. In an additional embodiment in block 4173, the default location may be a region determined as a function of a TDOA measurement and/or where the region is the intersection of a hyperbola defined by said TDOA with a timing advance region applicable to a serving cell serving the mobile device. In yet a further embodiment in

block 4174, the default location may be determined as a function of a priori knowledge of sector coverage density.

[00185] Figure 42 is a flow chart for a method of locating a mobile device in a geographic region according to an embodiment of the present subject matter. With reference to Figure 42, at block 4210, a plurality of grid points may be provided in a geographic region where each of the grid points may include at least one characterizing parameter or characterizing function, and where each of the grid points is located on a grid defined over the geographic region. At block 4220, a plurality of NMRs may be provided for a mobile device in the geographic region, and at block 4230, an estimated location may be determined for the mobile device from one NMR as a function of the at least one parameter. Of course, one or more of the grid points may be randomly located within the geographic region, and one or more of the grid points may be located on a predetermined fixed uniform grid defined over the geographic region.

[00186] Figure 43 is a flow chart for a method of locating a mobile device in a geographic region according to another embodiment of the present subject matter. With reference to Figure 43, blocks 4310, 4320 and 4330 are similar to blocks 4210, 4220 and 4230, respectively. At block 4340, the determination of an estimated location for the mobile device may further include comparing an ordered list of cells neighboring a cell serving the mobile device in the one NMR to an ordered list of neighboring cells in the grid. The ordering may be in terms of any one of a number of parameters characterizing a respective NMR, *e.g.,* NC power level or NC measurement quality. At block 4350, an estimated location may be generated for the mobile device which may comprise a centroid of a cluster of best matching grid points in the grid, a highest joint probability matching grid point in the grid, a weighted sum of the locations of a set of matching grid points in the grid (exemplary weights may be defined by any number of means such as, but not limited to, a joint probability derived from individual pdfs, etc.), a weighted sum of clustered locations of a set of matching grid points in the grid (*i.e.,* cluster the locations of the matching grid points and then apply a cumulative probability for all contained grid

points in a cluster as a weight for the respective cluster), as a function of locations determined from subsets of the plurality of NMRs, or any combination thereof. At block 4360, a further embodiment may also filter available grid points as a function of any one or combination of selected characteristics, such as, but not limited to, a matching of serving cell or sector for grid points in the grid to the serving cell (provided such a characterization is available for the respective grid points) or sector of the one NMR, a TA parameter from the one NMR, a RTT parameter from the one NMR, a mobile device orientation parameter, a serving cell identifier, a serving control channel, a magnitude of a serving cell forward link control channel received signal level, a predetermined number of cell received signal levels common to the one NMR, or any combination thereof.

[00187] Figure 44 is a flow chart for a method of locating a mobile device in a geographic region according to an additional embodiment of the present subject matter. With reference to Figure 44, blocks 4410, 4420 and 4430 are similar to blocks 4210, 4220 and 4230, respectively. At block 4440, the determination of an estimated location for the mobile device may further include comparing an ordered list of cells neighboring a cell serving the mobile device in the one NMR to a similarly ordered list of neighboring cells in the grid. The ordering may be in terms of any one of a number of parameters characterizing a respective NMR, *e.g.,* NC power level. At block 4450, if no exact match exists between the ordered list of neighboring cells of the one NMR and any grid point on the grid, then a largest subset of the ordered list of neighboring cells in the grid points may be formed that matches the NMR. At block 4460, an estimated location may be generated for the mobile device which may comprise a centroid of a cluster of thus matched grid points, clustered by location, in the grid, a highest joint probability matching grid point in the grid, a weighted sum of the locations of a set of matching grid points in the grid (exemplary weights may be defined by any number of means such as, but not limited to, a joint probability derived from individual pdfs, etc.), a weighted sum of clustered locations of a set of matching grid points in the grid (*i.e.,* cluster the locations of the matching grid points and then apply a cumulative probability for all contained grid

points in a cluster as a weight for the respective cluster), as a function of locations determined from subsets of the plurality of NMRs, or any combination thereof. At block 4470, a further embodiment may also filter available grid points as a function of any one or combination of selected characteristics, such as, but not limited to, a matching of serving cell or sector for grid points (provided such a characterization is available for those grid points) in the grid to the serving cell or sector of the one NMR, a TA parameter from the one NMR, a RTT parameter from the one NMR, a mobile device orientation parameter, a serving cell identifier, a serving control channel, a magnitude of a serving cell forward link control channel received signal level, a predetermined number of cell received signal levels common to the one NMR, or any combination thereof.

[00188] Figure 45 is a flow chart for a method of locating a mobile device in a geographic region according to a further embodiment of the present subject matter. With reference to Figure 45, blocks 4510, 4520 and 4530 are similar to blocks 4210, 4220 and 4230, respectively. At block 4540, the determination of an estimated location for the mobile device may further include comparing an ordered list of cells neighboring a cell serving the mobile device in the one NMR to an ordered list of neighboring cells in the grid. The ordering may be in terms of any one of a number of parameters characterizing a respective NMR, *e.g.,* NC power level. At block 4550, if the ordered list of neighboring cells of the one NMR is not contained in the ordered list of neighboring cells for the grid, then a largest ordered subset of neighboring cells in the one NMR may be utilized having either an exact match or is contained in the ordered list of neighboring cells in the grid. At block 4560, an estimated location of the mobile device may be generated that may comprise a centroid of a cluster, clustered by location, of thus matched grid points in the grid, a highest joint probability matching grid point in the grid, a weighted sum of the locations of a set of matching grid points in the grid (exemplary weights may be defined by any number of means such as, but not limited to, a joint probability derived from individual pdfs, etc.), a weighted sum of clustered locations of a set of matching grid points in the grid (*i.e.,* cluster the locations of the matching grid

points and then apply a cumulative probability for all contained grid points in a cluster as a weight for the respective cluster), and as a function of locations determined from subsets of the plurality of NMRs. At block 4570, a further embodiment may also filter available grid points as a function of any one or combination of selected characteristics, such as, but not limited to, a matching of serving cell or sector for grid points (provided such a characterization is available for those grid points) in the grid to the serving cell or sector of the one NMR, a TA parameter from the one NMR, a RTT parameter from the one NMR, a mobile device orientation parameter, a serving cell identifier, a serving control channel, a magnitude of a serving cell forward link control channel received signal level, a predetermined number of cell received signal levels common to the one NMR, or any combination thereof.

[00189] Figure 46 is a flow chart for a method of locating a mobile device in a geographic region according to yet another embodiment of the present subject matter. With reference to Figure 46, blocks 4610, 4620 and 4630 are similar to blocks 4210, 4220 and 4230, respectively. At block 4640, the determination of an estimated location for the mobile device may further include evaluating a probability density function for each power level of a cell neighboring a cell serving the mobile device in the one NMR over each grid point of a set of available grid points in the grid. At block 4650, a joint probability may then be determined as a function of the individual probability density functions, and at block 4660, an estimated location of the mobile device may be generated that may comprise a centroid of a cluster of highest probability grid points, clustered by location, in the grid, a highest joint probability matching grid point in the grid, a weighted sum of the locations of a set of matching grid points in the grid (exemplary weights may be defined by any number of means such as, but not limited to, a joint probability derived from individual pdfs, etc.), a weighted sum of clustered locations of a set of matching grid points in the grid (*i.e.,* cluster the locations of the matching grid points and then apply a cumulative probability for all contained grid points in a cluster as a weight for the respective cluster), and as a function of locations

determined from subsets of the plurality of NMRs. At block 4670, a further embodiment may also filter available grid points as a function of any one or combination of selected characteristics, such as, but not limited to, a matching of serving cell or sector for grid points (provided such a characterization is available for the respective grid points) in the grid to the serving cell or sector of the one NMR, a TA parameter from the one NMR, a RTT parameter from the one NMR, a mobile device orientation parameter, a serving cell identifier, a serving control channel, a magnitude of a serving cell forward link control channel received signal level, a predetermined number of cell received signal levels common to the one NMR, or any combination thereof.

[00190] Figure 47 is a flow chart for a method of locating a mobile device in a geographic region according to yet another embodiment of the present subject matter. With reference to Figure 47, blocks 4710, 4720 and 4730 are similar to blocks 4210, 4220 and 4230, respectively. At block 4740, the determination of an estimated location for the mobile device may further include directly evaluating a joint probability (*i.e.,* as an aggregate rather than through computation of the product of marginal pdfs) of power levels for at least one cell neighboring a cell serving the mobile device in the one NMR over a set of available grid points in the grid. At block 4750, an estimated location of the mobile device may be generated that may comprise a highest joint probability matching grid point in the grid, a weighted sum of the locations of a set of matching grid points in the grid (exemplary weights may be defined by any number of means such as, but not limited to, a joint probability derived from individual pdfs, etc.), a weighted sum of clustered locations of a set of matching grid points in the grid (*i.e.,* cluster the locations of the matching grid points and then apply a cumulative probability for all contained grid points in a cluster as a weight for the respective cluster), and as a function of locations determined from subsets of the plurality of NMRs. At block 4760, a further embodiment may also filter available grid points as a function of any one or combination of selected characteristics, such as, but not limited to, a matching of serving cell or sector for grid points (provided such a characterization is available for the respective grid points) in the

grid to the serving cell or sector of the one NMR, a TA parameter from the one NMR, a RTT parameter from the one NMR, a mobile device orientation parameter, a serving cell identifier, a serving control channel, a magnitude of a serving cell forward link control channel received signal level, a predetermined number of cell received signal levels common to the one NMR, or any combination thereof.

[00191] Figure 48 is a flow chart for a method of locating a mobile device in a geographic region according to yet another embodiment of the present subject matter. With reference to Figure 48, blocks 4810, 4820 and 4830 are similar to blocks 4210, 4220 and 4230, respectively. At block 4840, the determination of an estimated location for the mobile device may further include determining a distortion measure between a characteristic function or parameter of a grid point and a corresponding function or parameter obtained for the one NMR. At block 4850, an estimated location of the mobile device may be generated that may comprise a location of a grid point having the smallest distortion measure, a weighted sum of the locations of a set of matching grid points in the grid (where the weighting applied to each of the matching grid points may be a function of the distortion measure), a weighted sum of clustered locations of a set of matching grid points in the grid, as a function of locations determined from subsets of the plurality of NMRs, or any combination thereof. At block 4860, a further embodiment may also filter available grid points as a function of any one or combination of selected characteristics, such as, but not limited to, a matching of serving cell or sector for grid points (provided such a characterization is available for the respective grid points) in the grid to the serving cell or sector of the one NMR, a TA parameter from the one NMR, a RTT parameter from the one NMR, a mobile device orientation parameter, a serving cell identifier, a serving control channel, a magnitude of a serving cell forward link control channel received signal level, a predetermined number of cell received signal levels common to the one NMR, or any combination thereof. In an additional embodiment, the distortion measure may be, but is not limited to, a Mahalanobis distance.

[00192] Figure 49 is a flow chart for a method of locating a mobile device in a geographic region according to yet another embodiment of the present subject matter. With reference to Figure 49, blocks 4910, 4920 and 4930 are similar to blocks 4210, 4220 and 4230, respectively. At block 4940, the determination of an estimated location for the mobile device may further include matching cell power ordering of cells neighboring a cell serving the mobile device in the one NMR to neighboring cell power ordering in each of the grid points in the grid. At block 4950, an estimated location may then be selected as a function of a quality of the matching. The quality may be a function of a relative shift in the ordering sequence occurring between the one NMR and grid point cell power ordering. It is also envisioned that this same concept may be applied to any other vector parameter characterizing NMRs and/or grid points and such an example should not limit the scope of the claims appended herewith. At block 4960, a further embodiment may also filter available grid points as a function of any one or combination of selected characteristics, such as, but not limited to, a matching of serving cell or sector for grid points (provided such a characterization is available for the respective grid points) in the grid to the serving cell or sector of the one NMR, a TA parameter from the one NMR, a RTT parameter from the one NMR, a mobile device orientation parameter, a serving cell identifier, a serving control channel, a magnitude of a serving cell forward link control channel received signal level, a predetermined number of cell received signal levels common to the one NMR, or any combination thereof.

[00193] Figure 50 is a flow chart for another method of locating a mobile device in a geographic region according to an embodiment of the present subject matter. With reference to Figure 50, at block 5010, a plurality of grid points may be provided in a geographic region where each of the grid points may include at least one characterizing parameter and each of the grid points may be located on a grid defined over the geographic region. At block 5020, a plurality of NMRs may be provided for a mobile device in the geographic region, and at block 5030, an estimated location may be determined for the mobile device from a set of said plurality of network measurement

reports as a function of the parameter. Of course, one or more of the grid points may be randomly located within the geographic region, and one or more of the grid points may be located on a predetermined fixed uniform grid defined over the geographic region.

[00194] Figure 51 is a flow chart for another method of locating a mobile device in a geographic region according to an embodiment of the present subject matter. With reference to Figure 51, blocks 5110, 5120 and 5130 are similar to blocks 5010, 5020 and 5030, respectively. At block 5140, the determination of an estimated location for the mobile device may also include determining a cluster for each NMR characteristic or parameter, clustered by location, in the set of NMRs. The clustering may further be weighted by an exemplary metric that may be, but is not limited to, a Mahalanobis distance, joint probability, probability density function, and any combination thereof.

[00195] Figure 52 is a flow chart for another method of locating a mobile device in a geographic region according to an additional embodiment of the present subject matter. With reference to Figure 52, blocks 5210, 5220 and 5230 are similar to blocks 5010, 5020 and 5030, respectively. At block 5240, the determination of an estimated location for the mobile device may include determining a representative value for each parameter occurring in the set of NMRs. At block 5250, a cluster for each representative value may also be weighted by an exemplary metric (*e.g.*, a Mahalanobis distance, joint probability, probability density function, etc.) to weight the cluster. An exemplary representative value may be, but is not limited to, serving cell power level, neighboring cell power level, timing advance, round trip time, or any combination thereof. Further, the representative value may be determined as a function of a mean or median of a set of parameter values obtained over the set of NMRs.

[00196] Figure 53 is a flow chart for another method of locating a mobile device in a geographic region according to a further embodiment of the present subject matter. With reference to Figure 53, blocks 5310, 5320 and 5330 are similar to blocks 5010, 5020 and 5030, respectively. At block 5340, the determination of an estimated location

for the mobile device may also include observing a transition in a parameter occurring in one or more of the NMRs within an applicable set of NMRs. At block 5350, a location of the mobile device may be estimated on a boundary defined by a first range represented by the parameter before the transition and by a second range represented by the parameter after the transition. An exemplary parameter may be, but is not limited to, signal power level, signal quality, rate of dropping in/out of a neighboring cell signal, pattern of dropping in/out of a neighboring cell signal, changes in serving cell, changes in serving sector, RTT, TA, and any combinations thereof.

[00197] Figure 54 is a flow chart for another method of locating a mobile device in a geographic region according to an additional embodiment of the present subject matter. With reference to Figure 54, blocks 5410, 5420 and 5430 are similar to blocks 5010, 5020 and 5030, respectively. At block 5440, the determination of an estimated location for the mobile device may also determine a distortion measure between a parameter or function of ones of the grid points and a corresponding parameter or function in each NMR in the set. At block 5450, an estimated location of the mobile device may be generated where the estimated location may be, but is not limited to, a location of the grid point having the smallest distortion measure, a weighted sum of the locations of a set of matching grid points in the grid (where the weighting applied to each grid point may be a function of the distortion measure), a weighted sum of clustered locations of a set of matching grid points in the grid (*i.e.,* cluster the locations of the matching grid points and then apply a cumulative probability for all contained grid points in a cluster as a weight for the respective cluster), as a function of estimated locations determined from subsets of the set of NMRs by the preceding methods, and any combination thereof. An exemplary distortion measure may be, but is not limited to, a Mahalanobis distance.

[00198] Figure 55 is a flow chart for another method of locating a mobile device in a geographic region according to yet another embodiment of the present subject matter. With reference to Figure 55, blocks 5510, 5520 and 5530 are similar to blocks 5010, 5020 and 5030, respectively. At block 5540, the determination of an estimated location

for the mobile device may determine a representative value for each cell neighboring a serving cell serving the mobile device in the set of NMRs. More generally, for each parameter type held in common by an non-empty subset of the NMRs, a representative value may be generated. At block 5550, a distortion measure for each representative value may be determined as a function of a comparison between a parameter of ones of the grid points and a corresponding parameter for each representative value. At block 5560, an estimated location of the mobile device may be generated where the estimated location may comprise a location of the grid point having the smallest overall distortion measure (computed over all parameters of the set of NMRs), a weighted sum of the locations of a set of matching grid points in the grid (where the weighting may be a function of the distortion measure), a weighted sum of clustered locations of a set of matching grid points in the grid, as a function of estimated locations determined from subsets of the set of NMRs by the preceding methods, or any combination thereof.

[00199] Figure 56 is a flow chart for a method of estimating the location of a mobile device in a geographic region according to an embodiment of the present subject matter. With reference to Figure 56, at block 5610, calibration data may be provided for each of one or more calibration points in a geographic region where the calibration data may include a collection of NMRs having associated known locations. Of course, each of the NMRs provide at least one characterizing parameter. The calibration data may take the form of a collection of NMRs having associated locations as discussed above. Exemplary NMRs in the calibration data may be defined as an (n x1) vector with n parameters. Exemplary parameters may be, but are not limited to, observed power levels for adjacent neighbor cell control channels, TAs, RTTs, etc., each of which are a set of observed or collected information obtained at a particular location. A particular value of n, *i.e.*, the size of each NMR vector, may be variable (*e.g.*, n may range from at least one to fifteen or higher within a respective calibration data set). At block 5610, a candidate NMR may also be received from a mobile device at an unknown location. Thus, the geographical location from which the candidate NMR was generated should be estimated.

At block 5620, a first region may be defined within the calibration data as a function of a first characterizing parameter of the candidate NMR and a predetermined range of the first parameter. At block 5630, a second region may be defined within the calibration data as a function of a second characterizing parameter of the candidate NMR and a predetermined range of the second parameter.

[00200] By way of a non-limiting example, if the candidate NMR is a (4 x 1) vector including components that represent the power levels observed for some cells A, B and H and a fourth component that represents a TA value with respect to cell D, the candidate NMR vector may be provided by the following relationship:

$$NMR\_c = \begin{bmatrix} Pa \\ Pb \\ Ph \\ TAd \end{bmatrix} \quad (12)$$

[00201] With reference to Equation 12, if the first characterizing parameter of the candidate NMR considered is the power level observed for cell A, then the calibration data may be examined for each NMR (or data vector) having a power level observed for cell A that may be within a predetermined range about the value *Pa*. A set of such exemplary NMRs (or data vectors) within the calibration data satisfying this condition defines a region *R1* in a two dimensional location space where a location is desired. As each such piece of calibration data (*e.g.*, each NMR in the calibration data) that fits (*i.e.*, fits the range constraint upon the first parameter) has an associated location, it follows that a collection of such pieces or data vectors of calibration data may define a region. Further, assuming the second characterizing parameter considered is the power level observed for cell H, the same technique may also be applied to generate a second region *R2*. These regions may then represent areas in a location space that are potential or candidate solution regions for the location of the unknown (*e.g.*, candidate) NMR. The intersection of these two (or more) regions defines a region satisfying the two characterizing parameters considered within a respective range for each. Of course, a

multitude of parameters may be considered and a multitude of regions defined, thus, the simplistic example provided above should not limit the scope of the claims appended herewith.

[00202] The steps represented by blocks 5620 and 5630 may be repeated for each characterizing parameter in the candidate NMR and calibration data at block 5640. An intersection of the defined regions may be determined at block 5650 and at block 5660, the location of a mobile device in the geographic region may be estimated as a function of the intersection. It may be noted that any such intersection region may be equivalent to the geographic locations of the set of corresponding calibration points whose parameters, when suitably expanded in range define this intersection region. Alternatively, the intersection region can be equivalently treated as a subset of the original calibration points obtained by expanding the parameter ranges of the candidate NMR. Any one or plural calibration points may be located on a predetermined fixed uniform grid defined over the geographic region or randomly located within said geographic region. The calibration data may also comprise information from at least one NMR, may be obtained from one or more mobile devices located in close proximity to the one calibration point, and/or may be obtained from a signal transmitted from a mobile device in close proximity to the one calibration point and received at a receiver in or in proximity to the geographic region. In one embodiment of the present subject matter for each of select ones of the calibration points, the calibration data may include plural data vectors and the evaluating of the calibration data may comprise a determination of clustering of the plural data vectors.

[00203] Figure 57 is a flow chart for another method of estimating the location of a mobile device in a geographic region according to an embodiment of the present subject matter. With reference to Figure 57, blocks 5710, 5720, 5730, 5740, 5750 and 5760 are similar to blocks 5610, 5620, 5630, 5640, 5650 and 5660, respectively. At block 5770, the estimation of the location of a mobile device may further comprise estimating the location of a mobile device as a function of a statistical measure for calibration data of

select ones of the calibration points (these calibration points may correspond to the final intersection). An exemplary statistical measure may be, but is not limited to, a probability density function. At block 5780, in one embodiment of the present subject matter the estimated location of a mobile device may be the centroid of the intersection.

[00204] Figure 58 is a flow chart for a method of estimating the location of a mobile device in a geographic region according to one embodiment of the present subject matter. With reference to Figure 58, blocks 5810, 5820, 5830, 5840, 5850 and 5860 are similar to blocks 5610, 5620, 5630, 5640, 5650 and 5660, respectively. At block 5870, in one embodiment, the intersection may be determined as a function of a distortion measure.

[00205] Figure 59 is a flow chart for a method of estimating the location of a mobile device in a geographic region according to a further embodiment of the present subject matter. With reference to Figure 59, blocks 5910, 5920, 5930, 5940, 5950 and 5960 are similar to blocks 5610, 5620, 5630, 5640, 5650 and 5660, respectively. At block 5961, in one embodiment of the present subject matter the estimation of the location of a mobile device may comprise (a) comparing an ordered list of cells neighboring a cell serving the mobile device in the at least one NMR to an ordered list of neighboring cells in the intersection region or intersection (the ordering may be in terms of any one of a number of parameters characterizing a respective NMR, *e.g.,* NC power level or NC measurement quality), and (b) generating an estimated location of the mobile device. The estimated location may be, but is not limited to, a centroid of a cluster of best matching calibration points in the intersection region, a highest joint probability matching calibration point in the intersection region, a weighted sum of the locations of a set of matching calibration points in the intersection region (exemplary weights may be defined by any number of means such as, but not limited to, a joint probability derived from individual pdfs, etc.), a weighted sum of clustered locations of a set of matching calibration points in the intersection region (*i.e.,* cluster the locations of the matching grid points and then apply a cumulative probability for all contained grid points in a cluster as a weight for the

respective cluster), as a function of estimated locations determined from a subset of the at least one NMR, or any combination thereof.

[00206] In another embodiment of the present subject matter, at block 5962, the estimation of the location of a mobile device may comprise (a) comparing an ordered list of cells neighboring a cell serving the mobile device in the at least one NMR to a similarly ordered list of neighboring cells in the intersection region (the ordering may be in terms of any one of a number of parameters characterizing a respective NMR, *e.g.,* NC power level), (b) if no exact match exists between the ordered list of neighboring cells of the at least one NMR and any calibration point in the intersection region then a subset of the largest ordered list of neighboring cells may be formed in the intersection region, and (c) generating an estimated location of the mobile device. The estimated location may be, but is not limited to, a centroid of a cluster of matched calibration points in the intersection region, a highest joint probability matching calibration point in the intersection region, a weighted sum of the locations of a set of matching calibration points in the intersection region (exemplary weights may be defined by any number of means such as, but not limited to, a joint probability derived from individual pdfs, etc.), a weighted sum of clustered locations of a set of matching calibration points in the intersection region (*i.e.,* cluster the locations of the matching grid points and then apply a cumulative probability for all contained grid points in a cluster as a weight for the respective cluster), as a function of estimated locations determined from a subset of the at least one NMR, or any combination thereof.

[00207] At block 5963, the estimation of the location of a mobile device may comprise in a further embodiment of the present subject matter (a) comparing an ordered list of cells neighboring a cell serving the mobile device in the at least one NMR to an ordered list of neighboring cells in the intersection region (the ordering may be in terms of any one of a number of parameters characterizing a respective NMR, *e.g.,* NC power level), (b) if the ordered list of neighboring cells of the at least one NMR is not contained in the ordered list of neighboring cells for the intersection region, then a largest ordered

subset of neighboring cells in the at least one NMR may be utilized having either an exact match or is contained in the ordered list of neighboring cells in the intersection region, and (c) generating an estimated location of the mobile device. The estimated location may be, but is not limited to, a centroid of a cluster of matched calibration points in the intersection region, a highest joint probability matching calibration point in the intersection region, a weighted sum of the locations of a set of matching calibration points in the intersection region (exemplary weights may be defined by any number of means such as, but not limited to, a joint probability derived from individual pdfs, etc.), a weighted sum of clustered locations of a set of matching calibration points in the intersection region (*i.e.,* cluster the locations of the matching grid points and then apply a cumulative probability for all contained grid points in a cluster as a weight for the respective cluster), as a function of estimated locations determined from a subset of the at least one NMR, or any combination thereof.

[00208] At block 5964, in another embodiment of the present subject matter the estimation of the location of a mobile device may comprise (a) evaluating a pdf for each parameter of a cell neighboring a cell serving the mobile device in the at least one NMR over each calibration point in a set of available calibration points in the intersection region, (b) determining a joint probability as a function of the pdfs, and (c) generating an estimated location of the mobile device. The estimated location may be, but is not limited to, a centroid of a cluster of highest probability calibration points, clustered by location, in the intersection region, a highest joint probability matching calibration point in the intersection region, a weighted sum of the locations of a set of matching calibration points in the intersection region (exemplary weights may be defined by any number of means such as, but not limited to, a joint probability derived from individual pdfs, etc.), a weighted sum of clustered locations of a set of matching calibration points in the intersection region (*i.e.,* cluster the locations of the matching grid points and then apply a cumulative probability for all contained grid points in a cluster as a weight for the

respective cluster), as a function of estimated locations determined from a subset of the at least one NMR, or any combination thereof.

[00209] At block 5965, the estimation of the location of a mobile device may comprise in one embodiment of the present subject matter (a) directly evaluating a joint probability (*i.e.,* as an aggregate rather than through computation of the product of marginal pdfs) of power levels for at least one cell neighboring a cell serving the mobile device in the at least one NMR over a set of available calibration points in the intersection region, and (b) generating an estimated location of the mobile device. The estimated location may be, but is not limited to, a highest joint probability matching calibration point in the intersection region, a weighted sum of the locations of a set of matching calibration points in the intersection region (exemplary weights may be defined by any number of means such as, but not limited to, a joint probability derived from individual pdfs, etc.), a weighted sum of clustered locations of a set of matching calibration points in the intersection region (*i.e.,* cluster the locations of the matching grid points and then apply a cumulative probability for all contained grid points in a cluster as a weight for the respective cluster), as a function of estimated locations determined from a subset of the at least one NMR, or any combination thereof.

[00210] At block 5966, the estimation of the location of a mobile device may comprise in an additional embodiment of the present subject matter (a) determining a distortion measure between a characteristic function or parameter of a calibration point and a corresponding function or parameter in the at least one NMR and (b) generating an estimated location of the mobile device. The estimated location may be, but is not limited to, a location of a calibration point having the smallest distortion measure, a weighted sum of the locations of a set of matching calibration points in the intersection region (where the weighting applied to each of the matching calibration points may be a function of the distortion measure), a weighted sum of clustered locations of a set of matching calibration points in the intersection region, as a function of locations determined from a subset of the at least one NMR, or any combination thereof.

Exemplary distortion measures are described above and may be, but are not limited to, a Mahalanobis distance, etc.

[00211] In one embodiment of the present subject matter, at block 5967 the estimation of the location of a mobile device may comprise (a) matching cell power ordering of cells neighboring a cell serving the mobile device in the at least one NMR to neighboring cell power ordering of calibration points in each of the calibration points in the intersection region and (b) selecting an estimated location as a function of a quality of the matching. The quality may be a function of a relative shift in the ordering sequence occurring between the at least one NMR and calibration point cell power ordering. It is also envisioned that this same concept may be applied to any other vector parameter characterizing NMRs and/or grid points and such an example should not limit the scope of the claims appended herewith.

[00212] Figure 60 is a flow chart for a method of estimating the location of a mobile device in a geographic region. At block 6010, calibration data may be provided for a plurality of calibration points in the geographic region. The calibration data may include at least one characterizing parameter and for each of select ones of the calibration points the calibration data may also include plural data vectors. Of course, the calibration data may include a collection of NMRs having associated known locations, each of the NMRs providing at least one characterizing parameter. The calibration data may take the form of a collection of NMRs having associated locations as discussed above. Exemplary NMRs in the calibration data may be defined as an (n x1) vector with n parameters. Exemplary parameters may be, but are not limited to, observed power levels for adjacent neighbor cell control channels, TAs, RTTs, etc., each of which are a set of observed or collected information obtained at a particular location. A particular value of n, *i.e.*, the size of each NMR vector, may also be variable (*e.g.*, n may range from at least one to fifteen or higher within a respective calibration data set). A candidate set of NMRs may also be received from a mobile device at an unknown location. Thus, the geographical location from which the candidate set was generated should be estimated.

[00213] At block 6020, a first region within the calibration data may be defined as a function of a first characterizing parameter of the set of NMRs and a predetermined range of the first parameter. At block 6030, a second region within the calibration data may be defined as a function of another characterizing parameter of the set of NMRs and a predetermined range of another parameter. By way of a non-limiting example, if the first characterizing parameter of the candidate set considered is the power level observed for a first cell, *A*, then the calibration data may be examined for each NMR in the set (or data vector) having a power level observed for cell *A* that may be within a predetermined range about the value *Pa*. Exemplary NMRs (or data vectors) within the calibration data satisfying this condition may defines a region in a two dimensional location space where a location is desired. As each such piece of calibration data that fits the range constraint upon the first parameter has an associated location, it follows that a collection of such pieces or data vectors of calibration data may define a region. Further, assuming the second characterizing parameter considered is the power level observed for cell *B*, the same technique may also be applied to generate a second region. These regions may then represent areas in a location space that are potential or candidate solution regions for the location of the unknown set of NMRs. The intersection of these two (or more) regions defines a region satisfying the two characterizing parameters considered within a respective range for each. Of course, a multitude of parameters may be considered and a multitude of regions defined, and an intersection of this multitude of regions may also be obtained. Thus, the simplistic example provided above should not limit the scope of the claims appended herewith.

[00214] The steps represented by blocks 6020 and 6030 may be repeated for each characterizing parameter in the set of calibration data at block 6040. At block 6050, a clustering of the plural data vectors, whether directly in the regions obtained or for those data vectors than are contained in the intersection, may be determined. In another embodiment of the present subject matter, the clustering may be determined as a function of a metric, such as, but not limited to, joint probability, Mahalanobis distance, cluster

radius, etc. It may be noted that clustering may also be generally viewed as a process generating an intersection region. At block 6060, a location of a mobile device in the intersection region may be estimated as a function of the clustering. In one embodiment, any number or combination of the calibration points may be located on a predetermined fixed uniform grid defined over the geographic region or may be randomly located within the geographic region. Further, any of the calibration data may comprise information from a network measurement report. The calibration data for one of the calibration points may be obtained from one or more mobile devices located in close proximity to the one calibration point in another embodiment, and/or the calibration data for one of the calibration points may be obtained from a signal transmitted from a mobile device in close proximity to the one calibration point and received at a receiver in or in proximity to the geographic region.

[00215] Figure 61 is a flow chart for a method of estimating the location of a mobile device in a geographic region according to another embodiment of the present subject matter. With reference to Figure 61, at block 6110, calibration data for each of one or more calibration points in a geographic region may be provided where the calibration data includes at least one characterizing parameter. Further, a set of network measurement reports may be received from a mobile device at an unknown location where at least one of the network measurement reports in the set also includes at least one characterizing parameter. At block 6120, a representative value may be determined for each available characterizing parameter in the set as a function of a variation of the available characterizing parameter in each network measurement report in the set. In one embodiment of the present subject matter, the representative value may be obtained as a function of an available set of representative values, may be determined as a function of a mean or median of an available set of representative values, or may be selected as a function of a predetermined range. At block 6130, one or more representative network measurement reports may be determined as a function of the representative value, and at block 6140 the location of a mobile device may be estimated in the geographic region as

a function of the one or more representative network measurement reports. Any one or plural calibration points may be located on a predetermined fixed uniform grid defined over the geographic region or randomly located within the geographic region. The calibration data may also comprise information from at least one NMR, may be obtained from one or more mobile devices located in close proximity to the one calibration point, and/or may be obtained from a signal transmitted from a mobile device in close proximity to the one calibration point and received at a receiver in or in proximity to the geographic region. In one embodiment of the present subject matter, for each of select ones of the calibration points, the calibration data may include plural data vectors and the evaluating of the calibration data may comprise a determination of clustering of the plural data vectors.

[00216] Figure 62 is a flow chart for a method of estimating the location of a mobile device in a geographic region according to a further embodiment of the present subject matter. With reference to Figure 62, blocks 6210, 6220, 6230 and 6240 are similar to blocks 6110, 6120, 6130 and 6140, respectively. In one embodiment the method may further define a first region as a function of a first representative value for a first characterizing parameter and a predetermined range of the first value at block 6250 and at block 6260 define a second region as a function of a second representative value for a second characterizing parameter and a predetermined range of the second value. The steps represented by blocks 6250 and 6260 may be repeated for each characterizing parameter in the one or more representative NMRs at block 6270. At block 6280, an intersection of each defined region may be determined and at block 6290, the location of a mobile device in the geographic region may be estimated as a function of the intersection. At block 6291, in one embodiment of the present subject matter the location of a mobile device may be estimated as the centroid of the intersection, or at block 6292, the location of the mobile device may be estimated as a function of a statistical measure for calibration data of select ones of the calibration points. An exemplary statistical measure may be, but is not limited to, a probability density function.

[00217] Figure 63 is a flow chart for a method of estimating the location of a mobile device in a geographic region according to an additional embodiment of the present subject matter. With reference to Figure 63, blocks 6310, 6320, 6330, 6340, 6350, 6360, 6370, 6380 and 6390 are similar to blocks 6210, 6220, 6230, 6240, 6250, 6260, 6270, 6280 and 6290, respectively. At block 6381, in one embodiment of the present subject matter an intersection of each defined region may be determined as a function of a distortion measure.

[00218] Figure 64 is a flow chart for a method of estimating the location of a mobile device in a geographic region according to a further embodiment of the present subject matter. With reference to Figure 64, blocks 6410, 6420, 6430, 6440, 6450, 6460, 6470, 6480 and 6490 are similar to blocks 6210, 6220, 6230, 6240, 6250, 6260, 6270, 6280 and 6290 respectively. At block 6491, in one embodiment of the present subject matter the estimation of the location of a mobile device may comprise (a) comparing an ordered list of cells neighboring a cell serving the mobile device in the one or more representative network measurement reports to an ordered list of neighboring cells in each calibration point of the intersection where the ordering may be a function of any parameter of the one or more representative network measurement reports (the ordering may be in terms of any one of a number of parameters characterizing a respective NMR, *e.g.,* NC power level or NC measurement quality); and (b) generating an estimated location of the mobile device. The estimated location may be, but is not limited to, a centroid of a cluster of matching calibration points in the intersection; a highest joint probability matching calibration point in the intersection; a weighted sum of the locations of a set of matching calibration points in the intersection (exemplary weights may be defined by any number of means such as, but not limited to, a joint probability derived from individual pdfs, etc.); a weighted sum of clustered locations of a set of matching calibration points in the intersection (*i.e.,* cluster the locations of the matching grid points and then apply a cumulative probability for all contained grid points in a cluster as a weight for the

respective cluster), and as a function of estimated locations determined from a subset of the one or more representative network measurement reports, or any combination thereof.

[00219] In another embodiment of the present subject matter, at block 6492, the estimation of the location of a mobile device may comprise (a) comparing an ordered list of cells neighboring a cell serving the mobile device in the one or more representative network measurement reports to an ordered list of neighboring cells in each calibration point of the intersection where the ordering may be a function of any parameter in the one or more representative network measurement reports (the ordering may be in terms of any one of a number of parameters characterizing a respective NMR, *e.g.,* NC power level or NC measurement quality), (b) if no exact match is made between the ordered list of neighboring cells of the one or more representative network measurement reports and any calibration point in the intersection then forming a largest subset of the ordered list of neighboring cells in the calibration points that provide a match, and (c) generating an estimated location of the mobile device. The estimated location may be, but is not limited to, a centroid of a cluster of matching calibration points in the intersection, a highest joint probability matching calibration point in the intersection, a weighted sum of the locations of a set of matching calibration points in the intersection (exemplary weights may be defined by any number of means such as, but not limited to, a joint probability derived from individual pdfs, etc.), a weighted sum of clustered locations of a set of matching calibration points in the intersection (*i.e.,* cluster the locations of the matching grid points and then apply a cumulative probability for all contained grid points in a cluster as a weight for the respective cluster), and as a function of estimated locations determined from a subset of the one or more representative network measurement reports, or any combination thereof.

[00220] At block 6493, the estimation of the location of a mobile device may comprise in a further embodiment of the present subject matter (a) comparing an ordered list of cells neighboring a cell serving the mobile device in the one or more representative network measurement reports to an ordered list of neighboring cells in each calibration

point of the intersection where the ordering may be a function of any parameter in the one or more representative network measurement reports (the ordering may be in terms of any one of a number of parameters characterizing a respective NMR, *e.g.,* NC power level), (b) if the ordered list of neighboring cells of the one or more representative network measurement reports is not contained in the ordered list of neighboring cells for the intersection then using a largest subset of ordered neighboring cells in the one or more representative network measurement reports having either an exact match or contained in the ordered list of neighboring cells in the intersection, and (c) generating an estimated location of the mobile device. The estimated location may be, but is not limited to, a centroid of a cluster of matching calibration points in the intersection, a highest joint probability matching calibration point in the intersection, a weighted sum of the locations of a set of matching calibration points in the intersection (exemplary weights may be defined by any number of means such as, but not limited to, a joint probability derived from individual pdfs, etc.), a weighted sum of clustered locations of a set of matching calibration points in the intersection (*i.e.,* cluster the locations of the matching grid points and then apply a cumulative probability for all contained grid points in a cluster as a weight for the respective cluster), and as a function of estimated locations determined from a subset of the one or more representative network measurement reports, or any combination thereof.

[00221] At block 6494, in another embodiment of the present subject matter the estimation of the location of a mobile device may comprise (a) evaluating a probability density function for each power level of a cell neighboring a cell serving the mobile device in the one or more representative network measurement reports over each calibration point in a set of available calibration points in the intersection, (b) determining a joint probability as a function of the individual probability density functions, and (c) generating an estimated location of the mobile device. The estimated location may be, but is not limited to, a highest joint probability matching calibration point in the intersection, a weighted sum of the locations of a set of matching calibration points in the

intersection (exemplary weights may be defined by any number of means such as, but not limited to, a joint probability derived from individual pdfs, etc.), a weighted sum of clustered locations of a set of matching calibration points in the intersection (*i.e.,* cluster the locations of the matching grid points and then apply a cumulative probability for all contained grid points in a cluster as a weight for the respective cluster), and as a function of estimated locations determined from a subset of the one or more representative network measurement reports, or any combination thereof.

[00222] At block 6495, the estimation of the location of a mobile device may comprise in one embodiment of the present subject matter (a) directly evaluating a joint probability (*i.e.,* as an aggregate rather than through computation of the product of marginal pdfs) of power levels for at least one cell neighboring a cell serving the mobile device in the one or more representative network measurement reports over a set of available calibration points in the intersection, and (b) generating an estimated location of the mobile device. The estimated location may be, but is not limited to, a highest joint probability matching calibration point in the intersection, a weighted sum of the locations of a set of matching calibration points in the intersection (exemplary weights may be defined by any number of means such as, but not limited to, a joint probability derived from individual pdfs, etc.), a weighted sum of clustered locations of a set of matching calibration points in the intersection (*i.e.,* cluster the locations of the matching grid points and then apply a cumulative probability for all contained grid points in a cluster as a weight for the respective cluster), and as a function of estimated locations determined from a subset of the one or more representative network measurement reports, or any combination thereof.

[00223] At block 6496, the estimation of the location of a mobile device may comprise in an additional embodiment of the present subject matter (a) determining a distortion measure between a parameter or function of a calibration point contained in the intersection and a corresponding parameter or function in the one or more network measurement reports, and (b) generating an estimated location of the mobile device. The

estimated location may be, but is not limited to, a location of a calibration point having the smallest distortion measure, a weighting of the locations of a set of matching calibration points in the intersection (where the weighting applied to each of the matching calibration points may be a function of the distortion measure), a weighted sum of clustered locations of a set of matching calibration points in the intersection, and as a function of estimated locations determined from a subset of the one or more representative network measurement reports. Exemplary distortion measures are described above and may be but, but are not limited to, a Mahalanobis distance, etc.

[00224] In one embodiment of the present subject matter, at block 6497 the estimation of the location of a mobile device may comprise (a) matching cell power ordering of cells neighboring a cell serving the mobile device in the one or more representative network measurement reports to neighboring cell power ordering of calibration points in each of the calibration points in the intersection region, and (b) selecting an estimated location as a function of a quality of the matching. The quality may be a function of a relative shift in the ordering sequence occurring between the one or more representative network measurement reports and calibration point cell power ordering. It is also envisioned that this same concept may be applied to any other vector parameter characterizing NMRs and/or grid points and such an example should not limit the scope of the claims appended herewith.

[00225] Figure 65 is a diagram for a system for estimating the location of a mobile device in a geographic region according to an embodiment of the present subject matter. With reference to Figure 65, at block 6510, the system may comprise a database and, at block 6520, a processor operably connected thereto for receiving calibration data for each of one or more calibration points in a geographic region where the calibration data may include at least one characterizing parameter. The processor may also be programmed to receive an NMR from a mobile device at an unknown location. The processor may be programmed to determine a first region within the calibration data as a function of a first characterizing parameter of the received NMR and a predetermined range of the first

parameter and repeat the determination for each characterizing parameter in the NMR at block 6521, and determine an intersection for each defined region at block 6522. The processor may be further programmed to estimate the location of a mobile device in the geographic region as a function of the intersection at block 6523. Any one or plural calibration points may be located on a predetermined fixed uniform grid defined over the geographic region or randomly located within said geographic region. The calibration data may also comprise information from at least one NMR, may be obtained from one or more mobile devices located in close proximity to the one calibration point, and/or may be obtained from a signal transmitted from a mobile device in close proximity to the one calibration point and received at a receiver in or in proximity to the geographic region. In one embodiment of the present subject matter for each of select ones of the calibration points, the calibration data may include plural data vectors and the evaluating of the calibration data may comprise a determination of clustering of the plural data vectors.

[00226] Figure 66 is a diagram for a system for estimating the location of a mobile device in a geographic region according to an additional embodiment of the present subject matter. With reference to Figure 66, at block 6610, the system may comprise a database and, at block 6620, a processor operably connected thereto for receiving calibration data for each of one or more calibration points in a geographic region where the calibration data may include at least one characterizing parameter. The processor may also receive a set of network measurement reports from a mobile device at an unknown location, at least one of the network measurement reports in the set may also include at least one characterizing parameter. The processor may be programmed to determine a representative value for each available characterizing parameter in the set as a function of a variation of the available characterizing parameter in each network measurement report in the set at block 6621 and determine one or more representative network measurement reports as a function of the representative value at block 6622. At block 6623, the processor may also be programmed to estimate the location of a mobile

device in the geographic region as a function of the one or more representative network measurement reports.

[00227] In a further embodiment, the processor may be programmed to determine a first region as a function of a first representative value for a first characterizing parameter and a predetermined range of the first value and repeat said determination for each characterizing parameter in the one or more representative network measurement reports, determine an intersection of each determined region. The processor may also be programmed to estimate the location of a mobile device in the geographic region as a function of the intersection. Of course, any one or plural calibration points may be located on a predetermined fixed uniform grid defined over the geographic region or randomly located within said geographic region. The calibration data may also comprise information from at least one NMR, may be obtained from one or more mobile devices located in close proximity to the one calibration point, and/or may be obtained from a signal transmitted from a mobile device in close proximity to the one calibration point and received at a receiver in or in proximity to the geographic region. In one embodiment of the present subject matter for each of select ones of the calibration points, the calibration data may include plural data vectors and the evaluating of the calibration data may comprise a determination of clustering of the plural data vectors.

[00228] Figure 67 is a flow chart for a method of determining the location of a mobile device in a geographic region according to one embodiment of the present subject matter. With reference to Figure 67, at block 6710, the method may comprise providing calibration data for each of one or more calibration points in a geographic region where the calibration data includes one or more characterizing parameters. At block 6710, at least one NMR from a mobile device at an unknown location may be received. Of course, a set of NMRs may also be received in another embodiment of the present subject matter. At block 6720, one or more sets of grid points for the calibration data may be generated, and at block 6730, the at least one network measurement report may be evaluated with each of the sets of grid points as a function of select ones of the

characterizing parameters. A set of grid points may be selected as a function of a predetermined criteria at block 6740, and at block 6750, the location of a mobile device may be determined in the geographic region as a function of the selected set of grid points. Exemplary predetermined criteria may be, but are not limited to, total probability, cluster radius, Euclidean norm, joint probability, and Mahalanobis distance. Of course, any one or plural grid points may be located on a predetermined fixed uniform grid defined over the geographic region or randomly located within the geographic region. The calibration data may also comprise information from at least one NMR. In one embodiment of the present subject matter for each of select ones of the grid points, the calibration data may include plural data vectors and the evaluating of the calibration data may comprise a determination of clustering of the plural data vectors. An exemplary characterizing parameter (which may have been extracted from the calibration points that were assigned to the corresponding grid point) may be, but is not limited to, signal strength for a signal transmitted by a transmitter having a known location as received by a receiver at the grid point, signal strength of a signal transmitted by a transmitter located at the grid point as received by a receiver at a known location, round trip time for a signal traveling between the grid point and a known location, timing advance of a signal received by the mobile device at the grid point, time difference of arrival of plural signals at the grid point with respect to a pair of known locations as measured by a receiver at the grid point or at the known locations, the identification of a serving cell or serving sector of the mobile device located at the grid point, a state of a wireless network serving the mobile device, and combinations thereof.

[00229] Figure 68 is a flow chart for a method of determining the location of a mobile device in a geographic region according to another embodiment of the present subject matter. With reference to Figure 68, blocks 6810, 6820, 6830, 6840, and 6850 are similar to blocks 6710, 6720, 6730, 6740, and 6750, respectively. At block 6831, in one embodiment of the present subject matter the evaluation of the at least one NMR may include (i) comparing select ones of the sets of grid points to at least one characterizing

parameter of the at least one NMR, (ii) generating a first location estimate of the mobile device for each parameter of the NMR, and (iii) determining a second location estimate of the mobile device as a function of at least one of the generated first location estimates. At block 6832, another embodiment of the present subject matter may further comprise the step of identifying and omitting outlier first location estimates by (i) determining a Mahalanobis distance from each first location estimate to the second location estimate, (ii) determining a distance threshold from a median of the Mahalanobis distances multiplied by a predetermined factor, and (iii) determining a third location estimate by averaging two or more of the first location estimates. First location estimates having a Mahalanobis distance to the second location estimate greater than the distance threshold may be omitted from the determined third location estimate.

[00230] At block 6833, embodiments of the present subject matter may determine a second location estimate by averaging two or more first location estimates, or omit a first location estimate having an error greater than a predetermined threshold, at block 6834. At block 6835, embodiments of the present subject matter may also determine a second location estimate by employing a weighted averaging of ones of the first location estimates, or at block 6836, determine a second location estimate by weighting a first location estimate by an inverse of a distance metric. At block 6837, embodiments of the present subject matter may also determine a second location estimate by normalizing a first location estimate by a sum of an inverse of a distance metric, or at block 6838, determine a second location estimate by weighting a first location estimate as a function of the number of reporting neighboring cells to a serving cell serving the mobile device.

[00231] Figure 69 is a flow chart for a method of determining the location of a mobile device in a geographic region according to a further embodiment of the present subject matter. With reference to Figure 69, blocks 6910, 6920, 6930, 6940 and 6950 are similar to blocks 6710, 6720, 6730, 6740, and 6750, respectively. At block 6931, in one embodiment of the present subject matter the evaluation of the at least one NMR may include (i) comparing an ordered list of cells neighboring a cell serving the mobile device

in the NMR to an ordered list of neighboring cells in each grid point of the geographic region where the ordering may be a function of any parameter of the NMR; and (ii) generating an estimated location of the mobile device. The estimated location may be, but is not limited to, a centroid of a cluster of matching grid points in the geographic region, a highest joint probability matching grid point in the geographic region, a weighted sum of the locations of a set of matching grid points in the geographic region (exemplary weights may be defined by any number of means such as, but not limited to, a joint probability derived from individual pdfs, etc.), a weighted sum of clustered locations of a set of matching grid points in the geographic region (*i.e.,* cluster the locations of the matching grid points and then apply a cumulative probability for all contained grid points in a cluster as a weight for the respective cluster), as a function of locations determined from subsets of the calibration data, and any combination thereof.

[00232] At block 6932 in another embodiment of the present subject matter, the evaluation of the at least one NMR may include (i) comparing an ordered list of cells neighboring a cell serving the mobile device in the NMR to an ordered list of neighboring cells in each grid point of the geographic region where the ordering may be a function of any parameter of the NMR, (ii) if no exact match is made between the ordered list of neighboring cells of the NMR and any grid point in the geographic region then forming a largest subset of the ordered list of neighboring cells in the grid points that provide a match, and (iii) generating an estimated location of the mobile device. The estimated location may be, but is not limited to a centroid of a cluster of matching grid points in the geographic region, a highest joint probability matching grid point in the geographic region, a weighted sum of the locations of a set of matching grid points in the geographic region (exemplary weights may be defined by any number of means such as, but not limited to, a joint probability derived from individual pdfs, etc.), a weighted sum of clustered locations of a set of matching grid points in the geographic region (*i.e.,* cluster the locations of the matching grid points and then apply a cumulative probability for all

contained grid points in a cluster as a weight for the respective cluster), as a function of locations determined from subsets of the calibration data, or any combination thereof.

[00233] In another embodiment of the present subject matter, the evaluation of the at least one NMR may comprise at block 6933 (i) comparing an ordered list of cells neighboring a cell serving the mobile device in the NMR to an ordered list of neighboring cells in each grid point of the geographic region, where the ordering may be a function of any parameter of the NMR, (ii) using a largest subset of neighboring cells in the NMR having either an exact match or is contained in the ordered list of neighboring cells in the geographic region if the ordered list of neighboring cells of the NMR is not contained in the ordered list of neighboring cells for the geographic region, and (iii) generating an estimated location of the mobile device. The estimated location may be, but is not limited to, a centroid of a cluster of matching grid points in the geographic region, a highest joint probability matching grid point in the geographic region, a weighted sum of the locations of a set of matching grid points in the geographic region (exemplary weights may be defined by any number of means such as, but not limited to, a joint probability derived from individual pdfs, etc.), a weighted sum of clustered locations of a set of matching grid points in the geographic region (*i.e.,* cluster the locations of the matching grid points and then apply a cumulative probability for all contained grid points in a cluster as a weight for the respective cluster), as a function of locations determined from subsets of the calibration data, or any combination thereof.

[00234] At block 6934, in another embodiment of the present subject matter the evaluation of the at least one NMR may include (i) evaluating a probability density function for each power level of a cell neighboring a cell serving the mobile device in the NMR over each grid point in a set of available grid points in the geographic region; (ii) determining a joint probability as a function of the individual pdfs, and (iii) generating an estimated location of the mobile device. The estimated location may be, but is not limited to, a highest joint probability matching grid point in the geographic region, a weighted sum of the locations of a set of matching grid points in the geographic region

(exemplary weights may be defined by any number of means such as, but not limited to, a joint probability derived from individual pdfs, etc.), a weighted sum of clustered locations of a set of matching grid points in the geographic region (*i.e.,* cluster the locations of the matching grid points and then apply a cumulative probability for all contained grid points in a cluster as a weight for the respective cluster), as a function of locations determined from subsets of the calibration data, or any combination thereof.

[00235] In an additional embodiment of the present subject matter, the evaluation of the at least one NMR may comprise at block 6935 (i) directly evaluating a joint probability (*i.e.,* as an aggregate rather than through computation of the product of marginal pdfs) of power levels for at least one cell neighboring a cell serving the mobile device in the NMR over a set of available grid points in the geographic region, and (ii) generating an estimated location of the mobile device. The estimated location may be, but is not limited to, a highest joint probability matching grid point in the geographic region, a weighted sum of the locations of a set of matching grid points in the geographic region (exemplary weights may be defined by any number of means such as, but not limited to, a joint probability derived from individual pdfs, etc.), a weighted sum of clustered locations of a set of matching grid points in the geographic region (*i.e.,* cluster the locations of the matching grid points and then apply a cumulative probability for all contained grid points in a cluster as a weight for the respective cluster), as a function of locations determined from subsets of the calibration data, or any combination thereof. At block 6936, the evaluation of the at least one NMR may include in another embodiment of the present subject matter (i) determining a distortion measure between a parameter of a grid point and a corresponding parameter in the NMR, and (ii) generating an estimated location of the mobile device. The estimated location may be, but is not limited to, a location of a grid point having the smallest distortion measure, a weighted sum of the locations of a set of matching grid points in the geographic region (where the weighted sum may be a function of the distortion measure), a weighted sum of clustered locations

of a set of matching grid points in the geographic region, as a function of locations determined from subsets of the calibration data.

[00236] In a further embodiment of the present subject matter, the evaluation of the at least one NMR may include at block 6937 (i) matching cell power ordering of cells neighboring a cell serving the mobile device in the NMR to neighboring cell power ordering of grid points in the geographic region, and (ii) selecting an estimated location as a function of a quality of the matching. An exemplary quality may be, but is not limited to, a function of a relative shift in an ordering sequence occurring between the NMR and grid point cell power ordering. At block 6938, the evaluation of the at least one NMR may comprise in another embodiment of the present subject matter (i) defining a first region within the calibration data as a function of a first characterizing parameter of the at least one NMR and a predetermined range of the first parameter, (ii) defining a second region within the calibration data as a function of another characterizing parameter of the at least one NMR and a predetermined range of the another parameter, and (iii) repeating steps (i) – (ii) for each characterizing parameter in the at least one NMR. The evaluation may further comprise (iv) determining an intersection of each defined region, and (v) estimating the location of a mobile device in the geographic region as a function of the intersection.

[00237] At block 6939, the evaluation of the at least one NMR may also comprise (i) defining a first region within the calibration data as a function of a first characterizing parameter of a NMR within a set of NMRs and a predetermined range of the first parameter, (ii) defining a second region within the calibration data as a function of another characterizing parameter of the NMR within the set of NMRs and a predetermined range of the another parameter, and (iii) repeating steps (i) – (ii) for each characterizing parameter in the set of NMRs. The evaluation may further include (iv) determining a clustering of data vectors in the set of NMRs, and (v) estimating the location of a mobile device in the geographic region as a function of the clustering. At block 6941, the evaluation of the at least one NMR may comprise in one embodiment of

the present subject matter (i) determining a representative value for each available characterizing parameter in a set of NMRs as a function of a variation of available characterizing parameters in each available network measurement report, (ii) determining one or more representative network measurement reports as a function of the representative value, and (iii) estimating the location of a mobile device in the geographic region as a function of the one or more representative network measurement reports. Another embodiment of the present subject matter may define a first region as a function of a first representative value for a first characterizing parameter and a predetermined range of the first value and define a second region as a function of a second representative value for a second characterizing parameter and a predetermined range of the second value. A multitude of regions may be defined for each characterizing parameter in the one or more representative network measurement reports. The method may further determine an intersection of each defined region, and estimate the location of a mobile device in the geographic region as a function of the intersection.

[00238] Figure 70 is a diagram for a system for determining the location of a mobile device in a geographic region according to an embodiment of the present subject matter. With reference to Figure 70, the system may comprise at block 7010 a database, and at block 7020 a processor for receiving calibration data for each of one or more calibration points in a geographic region and receiving at least one NMR from a mobile device at an unknown location in the geographic region. Of course, the calibration data and NMR may include at least one or plural characterizing parameters. At block 7021, the processor may be programmed to (i) generate one or more sets of grid points for the calibration data, (ii) evaluate the at least one NMR with each of the sets of grid points as a function of select ones of the characterizing parameters, (iii) select a set of grid points as a function of a predetermined criteria, and (iv) determine the location of a mobile device in the geographic region as a function of the selected set. Of course, the at least one NMR may be plural NMRs such as a set of NMRs. Exemplary predetermined criteria may be, but are not limited to, total probability, cluster radius, Euclidean norm,

joint probability, and Mahalanobis distance. Of course, any one or plural grid points may be located on a predetermined fixed uniform grid defined over the geographic region or randomly located within the geographic region. The calibration data may also comprise information from at least one NMR, may be obtained from one or more mobile devices located in close proximity to the one grid point, and/or may be obtained from a signal transmitted from a mobile device in close proximity to the one grid point and received at a receiver in or in proximity to the geographic region. In one embodiment of the present subject matter for each of select ones of the grid points, the calibration data may include plural data vectors and the evaluating of the calibration data may comprise a determination of clustering of the plural data vectors. An exemplary characterizing parameter (which may have been extracted from the calibration points that were assigned to the corresponding grid point) may be, but is not limited to, signal strength for a signal transmitted by a transmitter having a known location as received by a receiver at the grid point, signal strength of a signal transmitted by a transmitter located at the grid point as received by a receiver at a known location, round trip time for a signal traveling between the grid point and a known location, timing advance of a signal received by the mobile device at the grid point, time difference of arrival of plural signals at the grid point with respect to a pair of known locations as measured by a receiver at the grid point or at the known locations, the identification of a serving cell or serving sector of the mobile device located at the grid point, a state of a wireless network serving the mobile device, and combinations thereof.

[00239] Figure 71 is a diagram for a system for determining the location of a mobile device in a geographic region according to another embodiment of the present subject matter. With reference to Figure 71, blocks 7110, 7120 and 7121 are similar to blocks 7010, 7020 and 7021, respectively. At block 7122, in one embodiment of the present subject matter the processor may be programmed to (v) compare select ones of the sets of grid points to at least one characterizing parameter of the at least one NMR, (vi) generate a first location estimate of the mobile device for each parameter of the NMR, and (vii)

determine a second location estimate of the mobile device as a function of at least one of the generated first location estimates. At block 7123, in another embodiment of the present subject matter the processor may be programmed to identify and omit outlier first location estimates. The process may identify and omit outlier first location estimates by (1) determining a Mahalanobis distance from each first location estimate to the second location estimate, (2) determining a distance threshold from a median of the Mahalanobis distances multiplied by a predetermined factor, and (3) determining a third location estimate by averaging two or more of the first location estimates. First location estimates having a Mahalanobis distance to the second location estimate greater than the distance threshold may then be omitted from the determined third location estimate. At block 7124, the processor, in one embodiment, may be programmed to determine an estimated location for the mobile device from the at least one NMR as a function of at least one characterizing parameter.

[00240] Figure 72 is a diagram for a system for determining the location of a mobile device in a geographic region according to another embodiment of the present subject matter. With reference to Figure 72, blocks 7210 and 7220 are similar to blocks 7010 and 7020, respectively. At block 7221, in one embodiment of the present subject matter the processor may be programmed to (i) compare an ordered list of cells neighboring a cell serving the mobile device in the NMR to an ordered list of neighboring cells in each grid point of the geographic region, the ordering being a function of any parameter of the NMR, and (ii) generate an estimated location of the mobile device. The estimated location may be, but is not limited to, a centroid of a cluster of matching grid points in the geographic region, a highest joint probability matching grid point in the geographic region, a weighted sum of the locations of a set of matching grid points in the geographic region (exemplary weights may be defined by any number of means such as, but not limited to, a joint probability derived from individual pdfs, etc.), a weighted sum of clustered locations of a set of matching grid points in the geographic region (*i.e.,* cluster the locations of the matching grid points and then apply a cumulative probability for all

contained grid points in a cluster as a weight for the respective cluster), as a function of locations determined from subsets of the calibration data, and any combination thereof.

[00241] At block 7222 in another embodiment of the present subject matter, the processor may be programmed to (i) compare an ordered list of cells neighboring a cell serving the mobile device in the NMR to an ordered list of neighboring cells in each grid point of the geographic region, the ordering being a function of any parameter of the NMR, (ii) form a largest subset of the ordered list of neighboring cells in the geographic region if no exact match is made between the ordered list of neighboring cells of the NMR and any grid point in the geographic region, and (iii) generate an estimated location of the mobile device. The estimated location may be, but is not limited to a centroid of a cluster of matching grid points in the geographic region, a highest joint probability matching grid point in the geographic region, a weighted sum of the locations of a set of matching grid points in the geographic region (exemplary weights may be defined by any number of means such as, but not limited to, a joint probability derived from individual pdfs, etc.), a weighted sum of clustered locations of a set of matching grid points in the geographic region (*i.e.,* cluster the locations of the matching grid points and then apply a cumulative probability for all contained grid points in a cluster as a weight for the respective cluster), as a function of locations determined from subsets of the calibration data, or any combination thereof.

[00242] In another embodiment of the present subject matter, the processor may be programmed to, at block 7223 (i) compare an ordered list of cells neighboring a cell serving the mobile device in the NMR to an ordered list of neighboring cells in each grid point of the geographic region, the ordering being a function of any parameter of the NMR, (ii) if the ordered list of neighboring cells of the NMR is not contained in the ordered list of neighboring cells for the geographic region then use a largest subset of neighboring cells in the NMR having either an exact match or is contained in the ordered list of neighboring cells in the geographic region, and (iii) generate an estimated location of the mobile device. The estimated location may be, but is not limited to, a centroid of a

cluster of matching grid points in the geographic region, a highest joint probability matching grid point in the geographic region, a weighted sum of the locations of a set of matching grid points in the geographic region (exemplary weights may be defined by any number of means such as, but not limited to, a joint probability derived from individual pdfs, etc.), a weighted sum of clustered locations of a set of matching grid points in the geographic region (*i.e.,* cluster the locations of the matching grid points and then apply a cumulative probability for all contained grid points in a cluster as a weight for the respective cluster), as a function of locations determined from subsets of the calibration data, or any combination thereof.

[00243] At block 7224, in another embodiment of the present subject matter the processor may be programmed to (i) evaluate a pdf for each power level of a cell neighboring a cell serving the mobile device in the NMR over each grid point in a set of available grid points in the geographic region, (ii) determine a joint probability as a function of the individual pdfs, and (iii) generate an estimated location of the mobile device. The estimated location may be, but is not limited to, a highest joint probability matching grid point in the geographic region, a weighted sum of the locations of a set of matching grid points in the geographic region (exemplary weights may be defined by any number of means such as, but not limited to, a joint probability derived from individual pdfs, etc.), a weighted sum of clustered locations of a set of matching grid points in the geographic region (*i.e.,* cluster the locations of the matching grid points and then apply a cumulative probability for all contained grid points in a cluster as a weight for the respective cluster), as a function of locations determined from subsets of the calibration data, or any combination thereof.

[00244] In an additional embodiment of the present subject matter, the processor may be programmed to, at block 7225 (i) directly evaluate a joint probability (*i.e.,* as an aggregate rather than through computation of the product of marginal pdfs) of power levels for at least one cell neighboring a cell serving the mobile device in the NMR over a set of available grid points in the geographic region, and (ii) generate an estimated

location of the mobile device. The estimated location may be, but is not limited to, a highest joint probability matching grid point in the geographic region, a weighted sum of the locations of a set of matching grid points in the geographic region (exemplary weights may be defined by any number of means such as, but not limited to, a joint probability derived from individual pdfs, etc.), a weighted sum of clustered locations of a set of matching grid points in the geographic region (*i.e.,* cluster the locations of the matching grid points and then apply a cumulative probability for all contained grid points in a cluster as a weight for the respective cluster), as a function of locations determined from subsets of the calibration data, or any combination thereof. At block 7226, the processor may be programmed to (i) determine a distortion measure between a parameter of a grid point and a corresponding parameter in the NMR, and (ii) generate an estimated location of the mobile device. The estimated location may be, but is not limited to, a location of a grid point having the smallest distortion measure, a weighted sum of the locations of a set of matching grid points in the geographic region (where the weighted sum may be a function of the distortion measure), a weighted sum of clustered locations of a set of matching grid points in the geographic region, as a function of locations determined from subsets of the calibration data.

[00245] In a further embodiment of the present subject matter, the processor may be programmed to, at block 7227 (i) match cell power ordering of cells neighboring a cell serving the mobile device in the NMR to neighboring cell power ordering of grid points in the geographic region, and (ii) select an estimated location as a function of a quality of the matching. An exemplary quality may be, but is not limited to, a function of a relative shift in an ordering sequence occurring between the NMR and grid point cell power ordering.

[00246] At block 7228, in a further embodiment of the present subject matter the processor may be programmed to (v) determine a first region within the calibration data as a function of a first characterizing parameter of the at least one NMR and a predetermined range of said first parameter and repeat the determination for each

characterizing parameter in the at least one NMR, (vi) determine an intersection for each defined region, and (vii) estimate the location of a mobile device in the geographic region as a function of the intersection.

[00247] In yet another embodiment of the present subject matter, the processor may be programmed to, at block 7229 (v) determine a first region within the calibration data as a function of a first characterizing parameter in a set of NMRs and a predetermined range of the first parameter and repeat the determination for each characterizing parameter in the set of NMRs, (vi) determine a clustering of data vectors of the set, by location, in the geographic region, and (vii) estimate the location of a mobile device in the geographic region as a function of the clustering. At block 7230, the processor may also be programmed to in another embodiment of the present subject matter (v) determine a representative value for each available characterizing parameter in a set of NMRs as a function of a variation of available characterizing parameters in each available network measurement report, (vi) determine one or more representative NMRs as a function of the representative value, and (vii) estimate the location of a mobile device in the geographic region as a function of the one or more representative network measurement reports. A further embodiment of the processor may also determine a first region as a function of a first representative value for a first characterizing parameter and a predetermined range of said first value and repeat the determination for each characterizing parameter in the one or more representative network measurement reports. The processor may also determine an intersection of each defined region, and estimate the location of a mobile device in the geographic region as a function of the intersection.

[00248] As shown by the various configurations and embodiments illustrated in Figures 1-72, a method and system for generating a location estimate using uniform and non-uniform grid points have been described.

[00249] While preferred embodiments of the present subject matter have been described, it is to be understood that the embodiments described are illustrative only and

that the scope of the invention is to be defined solely by the appended claims when accorded a full range of equivalence, many variations and modifications naturally occurring to those of skill in the art from a perusal hereof.

WE CLAIM:

1. A method of determining the location of a mobile device in a geographic region comprising the steps of:

(a) providing calibration data for each of one or more calibration points in a geographic region, said calibration data having one or more characterizing parameters;

(b) generating one or more sets of grid points for said calibration data;

(c) receiving at least one network measurement report from a mobile device at an unknown location in said geographic region;

(d) evaluating said at least one network measurement report with each of said sets of grid points as a function of select ones of said characterizing parameters;

(e) selecting a set of grid points as a function of a predetermined criteria; and

(f) determining the location of a mobile device in said geographic region as a function of said selected set of grid points.

2. The method of Claim 1 wherein said at least one network measurement report is a set of network measurement reports.

3. The method of Claim 1 wherein said predetermined criteria is selected from the group consisting of: total probability, cluster radius, Euclidean norm, joint probability, and Mahalanobis distance.

4. The method of Claim 1 wherein one of said grid points is located on a predetermined fixed uniform grid defined over said geographic region.

5. The method of Claim 4 wherein one of said grid points is randomly located within said geographic region.

6. The method of Claim 1 wherein one of said grid points is randomly located within said geographic region.

7. The method of Claim 1 wherein said calibration data comprises information from a network measurement report.

8. The method of Claim 1 wherein for each of select ones of said grid points the calibration data includes plural data vectors and the evaluating of said sets of grid points comprises a determination of clustering of said plural data vectors.

9. The method of Claim 1 wherein said characterizing parameter is selected from the group consisting of: signal strength for a signal transmitted by a transmitter having a known location as received by a receiver at said grid point; signal strength of a signal transmitted by a transmitter located at said grid point as received by a receiver at a known location; round trip time for a signal traveling between said grid point and a known location; timing advance of a signal received by said mobile device at said grid point; time difference of arrival of plural signals at said grid point with respect to a pair of known locations as measured by a receiver at said grid point or at said known locations; the identification of a serving cell or serving sector of said mobile device located at said grid point; a state of a wireless network serving said mobile device, and combinations thereof.

10. The method of Claim 1 wherein the step of evaluating further comprises:

(i) comparing select ones of said sets of grid points to at least one characterizing parameter of said at least one network measurement report;

(ii) generating a first location estimate of the mobile device for each parameter of said network measurement report; and

(iii) determining a second location estimate of the mobile device as a function of at least one of said generated first location estimates.

11. The method of Claim 10 further comprising the step of identifying and omitting outlier first location estimates by:

(i) determining a Mahalanobis distance from each first location estimate to the second location estimate;

(ii) determining a distance threshold from a median of the Mahalanobis distances multiplied by a predetermined factor; and

(iii) determining a third location estimate by averaging two or more of said first location estimates,

wherein first location estimates having a Mahalanobis distance to the second location estimate greater than the distance threshold are omitted from said determined third location estimate.

12. The method of Claim 10 wherein determining a second location estimate further comprises averaging two or more first location estimates.

13. The method of Claim 10 further comprising the step of omitting a first location estimate having an error greater than a predetermined threshold.

14. The method of Claim 10 wherein determining a second location estimate further comprises employing a weighted averaging of ones of said first location estimates.

15. The method of Claim 10 wherein determining a second location estimate further comprises weighting a first location estimate by an inverse of a distance metric.

16. The method of Claim 10 wherein determining a second location estimate further comprises normalizing a first location estimate by a sum of an inverse of a distance metric.

17. The method of Claim 10 wherein determining a second location estimate further comprises weighting a first location estimate as a function of the number of reporting neighboring cells to a serving cell serving said mobile device.

18. The method of Claim 1 wherein the step of evaluating further comprises:

(i) comparing an ordered list of cells neighboring a cell serving said mobile device in said network measurement report to an ordered list of neighboring cells in each grid point of said geographic region, said ordering being a function of any parameter of said network measurement report; and

(ii) generating an estimated location of said mobile device wherein said estimated location is selected from the group consisting of: a centroid of a cluster of matching grid points in said geographic region; a highest joint probability matching grid point in said geographic region; a weighted sum of the locations of a set of matching grid points in said geographic region; a weighted sum of clustered locations of a set of matching grid points in said geographic region; and as a function of locations determined from subsets of said calibration data.

19. The method of Claim 1 wherein the step of evaluating further comprises:

(i) comparing an ordered list of cells neighboring a cell serving said mobile device in said network measurement report to an ordered list of neighboring cells in each grid point of said geographic region, said ordering being a function of any parameter of said network measurement report;

(ii) if no exact match is made between the ordered list of neighboring cells of said network measurement report and any grid point in said geographic region then forming a largest subset of the ordered list of neighboring cells in said grid points that provide a match; and

(iii) generating an estimated location of said mobile device wherein said estimated location is selected from the group consisting of: a centroid of a cluster of matching grid points in said geographic region; a highest joint probability matching grid point in said geographic region; a weighted sum of the locations of a set of matching grid points in said geographic region; a weighted sum of clustered locations of a set of matching grid points in said geographic region; and as a function of locations determined from subsets of said calibration data.

20. The method of Claim 1 wherein the step of evaluating further comprises:

(i) comparing an ordered list of cells neighboring a cell serving said mobile device in said network measurement report to an ordered list of neighboring cells in each grid point of said geographic region, said ordering being a function of any parameter of said network measurement report;

(ii) if the ordered list of neighboring cells of said network measurement report is not contained in the ordered list of neighboring cells for said geographic region then using a largest subset of neighboring cells in said network measurement report having either an exact match or is contained in the ordered list of neighboring cells in said geographic region; and

(iii) generating an estimated location of said mobile device wherein said estimated location is selected from the group consisting of: a centroid of a cluster of matching grid points in said geographic region; a highest joint probability matching grid point in said geographic region; a weighted sum of the locations of a set of matching grid points in said geographic region; a weighted sum of clustered locations of a set of matching grid points in said geographic region; and as a function of locations determined from subsets of said calibration data.

21. The method of Claim 1 wherein the step of evaluating further comprises:

(i) evaluating a probability density function for each power level of a cell neighboring a cell serving said mobile device in said network measurement report over each grid point in a set of available grid points in said geographic region;

(ii) determining a joint probability as a function of said individual probability density functions; and

(iii) generating an estimated location of said mobile device wherein said estimated location is selected from the group consisting of: a highest joint probability matching grid point in said geographic region; a weighted sum of the locations of a set of matching grid points in said geographic region; a weighted sum of clustered locations of

a set of matching grid points in said geographic region; and as a function of locations determined from subsets of said calibration data.

22. The method of Claim 1 wherein the step of evaluating further comprises:

(i) evaluating a joint probability of power levels for at least one cell neighboring a cell serving said mobile device in said network measurement report over a set of available grid points in said geographic region; and

(ii) generating an estimated location of said mobile device wherein said estimated location is selected from the group consisting of: a highest joint probability matching grid point in said geographic region; a weighted sum of the locations of a set of matching grid points in said geographic region; a weighted sum of clustered locations of a set of matching grid points in said geographic region; and as a function of locations determined from subsets of said calibration data.

23. The method of Claim 1 wherein the step of evaluating further comprises:

(i) determining a distortion measure between a parameter of a grid point and a corresponding parameter in said network measurement report; and

(ii) generating an estimated location of said mobile device wherein said estimated location is selected from the group consisting of: a location of a grid point having the smallest distortion measure; a weighted sum of the locations of a set of matching grid points in said geographic region, said weighted sum being a function of said distortion measure; a weighted sum of clustered locations of a set of matching grid points in said geographic region; and as a function of locations determined from subsets of said calibration data.

24. The method of Claim 1 wherein the step of evaluating further comprises:

(i) matching cell power ordering of cells neighboring a cell serving said mobile device in said network measurement report to neighboring cell power ordering of grid points in said geographic region; and

(ii) selecting an estimated location as a function of a quality of said matching, wherein said quality is a function of a relative shift in an ordering sequence occurring between said network measurement report and grid point cell power ordering.

25. The method of Claim 1 wherein the step of evaluating further comprises:

(i) defining a first region within said calibration data as a function of a first characterizing parameter of said at least one network measurement report and a predetermined range of said first parameter;

(ii) defining a second region within said calibration data as a function of another characterizing parameter of said at least one network measurement report and a predetermined range of said another parameter;

(iii) repeating steps (i) – (ii) for each characterizing parameter in said at least one network measurement report;

(iv) determining an intersection of each defined region; and

(v) estimating the location of a mobile device in said geographic region as a function of said intersection.

26. The method of Claim 1 wherein the step of evaluating further comprises:

(i) defining a first region within said calibration data as a function of a first characterizing parameter of a network measurement report within a set of network measurement reports and a predetermined range of said first parameter;

(ii) defining a second region within said calibration data as a function of another characterizing parameter of said network measurement report within the set of network measurement reports and a predetermined range of said another parameter;

(iii) repeating steps (i) – (ii) for each characterizing parameter in said set of network measurement reports;

(iv) determining a clustering of data vectors in said set of network measurement reports; and

(v) estimating the location of a mobile device in said geographic region as a function of said clustering.

27. The method of Claim 1 wherein the step of evaluating further comprises:

(i) determining a representative value for each available characterizing parameter in a set of network measurement reports as a function of a variation of said available characterizing parameter in each available network measurement report;

(ii) determining one or more representative network measurement reports as a function of said representative value; and

(iii) estimating the location of a mobile device in said geographic region as a function of said one or more representative network measurement reports.

28. The method of Claim 27 further comprising the steps of:

(iv) defining a first region as a function of a first representative value for a first characterizing parameter and a predetermined range of said first value;

(v) defining a second region as a function of a second representative value for a second characterizing parameter and a predetermined range of said second value;

(vi) repeating steps (iv) – (v) for each characterizing parameter in said one or more representative network measurement reports;

(vii) determining an intersection of each defined region; and

(viii) estimating the location of a mobile device in said geographic region as a function of said intersection.

29. The method of Claim 1 wherein the step of selecting further comprises selecting a set of grid points as a function of a criteria of fit.

30. The method of Claim 29 wherein the criteria of fit is selected from the group consisting of: total probability, cluster radius, Euclidean norm, Mahalanobis distance, distortion measure, confidence measure, and any combination thereof.

31. The method of Claim 1 wherein the step of selecting further comprises:

(i) selecting one or more candidate locations from one or more of said sets of grid points; and

(ii) evaluating said selected one or more candidate locations across said one or more sets of grid points,

wherein the determined location of the mobile device is a function of said evaluation of said selected locations.

32. A system for determining the location of a mobile device in a geographic region comprising:

(a) a database; and

(b) a processor for receiving calibration data for each of one or more calibration points in a geographic region and receiving at least one network measurement report from a mobile device at an unknown location in said geographic region, said calibration data and network measurement report having at least one characterizing parameter and said processor is programmed to:

(i) generate one or more sets of grid points for said calibration data,

(ii) evaluate said at least one network measurement report with each of said sets of grid points as a function of select ones of said characterizing parameters,

(iii) select a set of grid points as a function of a predetermined criteria, and

(iv) determine the location of a mobile device in said geographic region as a function of said selected set.

33. The system of Claim 32 wherein said at least one network measurement report is a set of network measurement reports.

34. The system of Claim 32 wherein said predetermined criteria is selected from the group consisting of: total probability, cluster radius, Euclidean norm, joint probability, and Mahalanobis distance.

35. The system of Claim 32 wherein one of said grid points is located on a predetermined fixed uniform grid defined over said geographic region.

36. The system of Claim 35 wherein one of said grid points is randomly located within said geographic region.

37. The system of Claim 32 wherein one of said grid points is randomly located within said geographic region.

38. The system of Claim 32 wherein said calibration data comprises information from a network measurement report.

39. The system of Claim 32 wherein for each of select ones of said grid points the calibration data includes plural data vectors and the evaluating of said grid points comprises a determination of clustering of said plural data vectors.

40. The system of Claim 32 wherein said characterizing parameter is selected from the group consisting of: signal strength for a signal transmitted by a transmitter having a known location as received by a receiver at said grid point; signal strength of a signal transmitted by a transmitter located at said grid point as received by a receiver at a known location; round trip time for a signal traveling between said grid point and a known location; timing advance of a signal received by said mobile device at said grid point; time difference of arrival of plural signals at said grid point with respect to a pair of known locations as measured by a receiver at said grid point or at said known locations; the identification of a serving cell or serving sector of said mobile device located at said grid point; a state of a wireless network serving said mobile device, and combinations thereof.

41. The system of Claim 32 wherein the processor is further programmed to:

(v) compare select ones of said sets of grid points to at least one characterizing parameter of said at least one network measurement report;

(vi) generate a first location estimate of the mobile device for each parameter of said network measurement report; and

(vii) determine a second location estimate of the mobile device as a function of at least one of said generated first location estimates.

42. The system of Claim 41 wherein the processor is further programmed to identify and omit outlier first location estimates by:

(1) determine a Mahalanobis distance from each first location estimate to the second location estimate;

(2) determine a distance threshold from a median of the Mahalanobis distances multiplied by a predetermined factor; and

(3) determine a third location estimate by averaging two or more of said first location estimates,

wherein first location estimates having a Mahalanobis distance to the second location estimate greater than the distance threshold are omitted from said determined third location estimate.

43. The system of Claim 32 wherein the processor is further programmed to:

(v) determine an estimated location for said mobile device from said at least one network measurement report as a function of at least one characterizing parameter.

44. The system of Claim 32 wherein the processor is further programmed to:

(v) compare an ordered list of cells neighboring a cell serving said mobile device in said network measurement report to an ordered list of neighboring cells in each grid point of said geographic region, said ordering being a function of any parameter of said network measurement report; and

(vi) generate an estimated location of said mobile device wherein said estimated location is selected from the group consisting of: a centroid of a cluster of matching grid points in said geographic region; a highest joint probability matching grid point in said geographic region; a weighted sum of the locations of a set of matching grid points in said geographic region; a weighted sum of clustered locations of a set of matching grid points in said geographic region; and as a function of locations determined from subsets of said calibration data.

45. The system of Claim 32 wherein the processor is further programmed to:

(v) compare an ordered list of cells neighboring a cell serving said mobile device in said network measurement report to an ordered list of neighboring cells in each grid point of said geographic region, said ordering being a function of any parameter of said network measurement report;

(vi) if no exact match is made between the ordered list of neighboring cells of said network measurement report and any grid point in said geographic region then form a largest subset of the ordered list of neighboring cells in said grid points that provide a match; and

(vii) generate an estimated location of said mobile device wherein said estimated location is selected from the group consisting of: a centroid of a cluster of matching grid points in said geographic region; a highest joint probability matching grid point in said geographic region; a weighted sum of the locations of a set of matching grid points in said geographic region; a weighted sum of clustered locations of a set of matching grid points in said geographic region; and as a function of locations determined from subsets of said calibration data.

46. The system of Claim 32 wherein the processor is further programmed to:

(v) compare an ordered list of cells neighboring a cell serving said mobile device in said network measurement report to an ordered list of neighboring cells in each grid point of said geographic region, said ordering being a function of any parameter of said network measurement report;

(vi) if the ordered list of neighboring cells of said network measurement report is not contained in the ordered list of neighboring cells for said geographic region then use a largest subset of neighboring cells in said network measurement report having either an exact match or is contained in the ordered list of neighboring cells in said geographic region; and

(vii) generate an estimated location of said mobile device wherein said estimated location is selected from the group consisting of: a centroid of a cluster of matching grid points in said geographic region; a highest joint probability matching grid point in said geographic region; a weighted sum of the locations of a set of matching grid points in said geographic region; a weighted sum of clustered locations of a set of matching grid

points in said geographic region; and as a function of locations determined from subsets of said calibration data.

47. The system of Claim 32 wherein the processor is further programmed to:

(v) evaluate a probability density function for each power level of a cell neighboring a cell serving said mobile device in said network measurement report over each grid point in a set of available grid points in said geographic region;

(vi) determine a joint probability as a function of said individual probability density functions; and

(vii) generate an estimated location of said mobile device wherein said estimated location is selected from the group consisting of: a highest joint probability matching grid point in said geographic region; a weighted sum of the locations of a set of matching grid points in said geographic region; a weighted sum of clustered locations of a set of matching grid points in said geographic region; and as a function of locations determined from subsets of said calibration data.

48. The system of Claim 32 wherein the processor is further programmed to:

(v) evaluate a joint probability of power levels for at least one cell neighboring a cell serving said mobile device in said network measurement report over a set of available grid points in said geographic region; and

(vi) generate an estimated location of said mobile device wherein said estimated location is selected from the group consisting of: a highest joint probability matching grid point in said geographic region; a weighted sum of the locations of a set of matching grid points in said geographic region; a weighted sum of clustered locations of a set of

matching grid points in said geographic region; and as a function of locations determined from subsets of said calibration data.

49. The system of Claim 32 wherein the processor is further programmed to:

(v) determine a distortion measure between a parameter of a grid point and a corresponding parameter in said network measurement report; and

(vi) generate an estimated location of said mobile device wherein said estimated location is selected from the group consisting of: a location of a grid point having the smallest distortion measure; a weighted sum of the locations of a set of matching grid points in said geographic region, said weighted sum being a function of said distortion measure; a weighted sum of clustered locations of a set of matching grid points in said geographic region; and as a function of locations determined from subsets of said calibration data.

50. The system of Claim 32 wherein the processor is further programmed to:

(v) match cell power ordering of cells neighboring a cell serving said mobile device in said network measurement report to neighboring cell power ordering of grid points in said geographic region; and

(vi) selecting an estimated location as a function of a quality of said matching, wherein said quality is a function of a relative shift in an ordering sequence occurring between said network measurement report and grid point cell power ordering.

51. The system of Claim 32 wherein the processor is further programmed to:

(v) determine a first region within said calibration data as a function of a first characterizing parameter of said at least one network measurement report and a

predetermined range of said first parameter and repeat said determination for each characterizing parameter in said at least one network measurement report;

(vi) determine an intersection for each defined region; and

(vii) estimate the location of a mobile device in said geographic region as a function of said intersection.

52. The system of Claim 32 wherein the processor is further programmed to:

(v) determine a first region within said calibration data as a function of a first characterizing parameter in a set of network measurement reports and a predetermined range of said first parameter and repeat said determination for each characterizing parameter in said set of network measurement reports;

(vi) determine a clustering of data vectors of said set, by location, in said geographic region; and

(vii) estimate the location of a mobile device in said geographic region as a function of said clustering.

53. The system of Claim 32 wherein the processor is further programmed to:

(v) determine a representative value for each available characterizing parameter in a set of network measurement reports as a function of a variation of available characterizing parameters in each available network measurement report;

(vi) determine one or more representative network measurement reports as a function of said representative value; and

(vii) estimate the location of a mobile device in said geographic region as a function of said one or more representative network measurement reports.

54. The system of Claim 53 wherein the processor is further programmed to:

(viii) determine a first region as a function of a first representative value for a first characterizing parameter and a predetermined range of said first value and repeat said determination for each characterizing parameter in said one or more representative network measurement reports;

(ix) determine an intersection of each defined region; and

(x) estimate the location of a mobile device in said geographic region as a function of said intersection.

55. The system of Claim 32 wherein the processor is further programmed to select a set of grid points as a function of a criteria of fit.

56. The system of Claim 55 wherein the criteria of fit is selected from the group consisting of: total probability, cluster radius, Euclidean norm, Mahalanobis distance, distortion measure, confidence measure, and any combination thereof.

57. The system of Claim 32 wherein the processor is further programmed to:

(i) select one or more candidate locations from one or more of said sets of grid points; and

(ii) evaluate said selected one or more candidate locations across said one or more sets of grid points,

wherein the determined location of the mobile device is a function of said evaluated selected locations.

Abstract

The location of a wireless mobile device may be estimated using, at least in part, one or more pre-existing Network Measurement Reports ("NMRs") which include calibration data for a number of locations within a geographic region. The calibration data for these locations is gathered and analyzed so that particular grid points within the geographic region can be determined and associated with a particular set or sets of calibration data from, for example, one or more NMRs. Sets of grid points may be evaluated as a function of parameters of the calibration data, and a set of grid points may be selected as a function of a predetermined criteria. The location of a mobile device in the geographic region may then be determined as a function of the predetermined criteria.

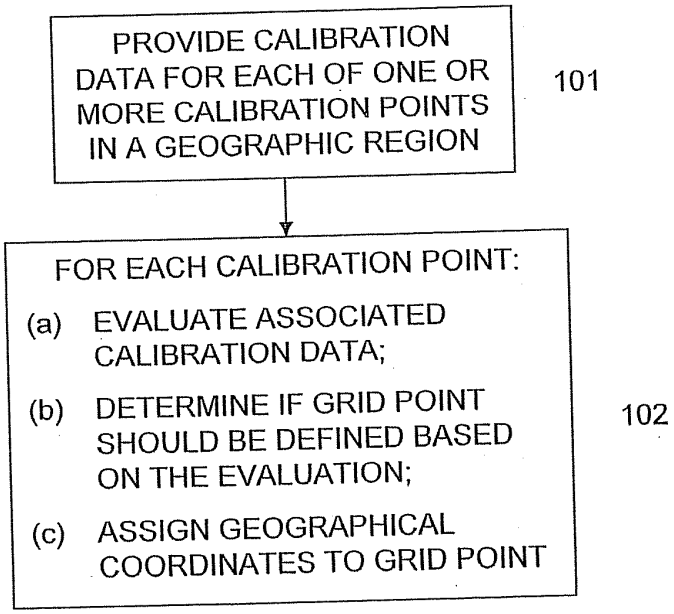
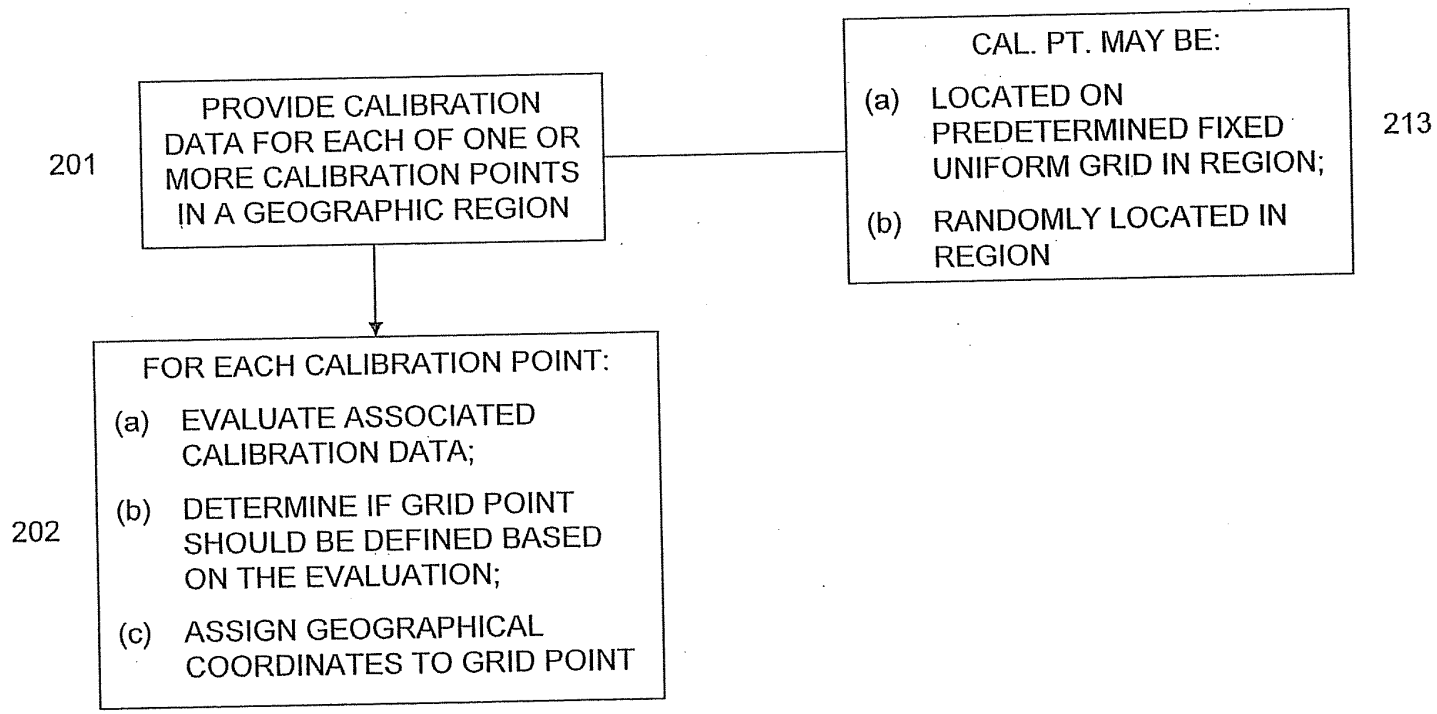

PROVIDE CALIBRATION DATA FOR EACH OF ONE OR MORE CALIBRATION POINTS IN A GEOGRAPHIC REGION
101
FOR EACH CALIBRATION POINT:
(a) EVALUATE ASSOCIATED CALIBRATION DATA;
(b) DETERMINE IF GRID POINT SHOULD BE DEFINED BASED ON THE EVALUATION;
(c) ASSIGN GEOGRAPHICAL COORDINATES TO GRID POINT
102

FIGURE 1


201
PROVIDE CALIBRATION DATA FOR EACH OF ONE OR MORE CALIBRATION POINTS IN A GEOGRAPHIC REGION
CAL. PT. MAY BE:
(a) LOCATED ON PREDETERMINED FIXED UNIFORM GRID IN REGION;
(b) RANDOMLY LOCATED IN REGION
213
202
FOR EACH CALIBRATION POINT:
(a) EVALUATE ASSOCIATED CALIBRATION DATA;
(b) DETERMINE IF GRID POINT SHOULD BE DEFINED BASED ON THE EVALUATION;
(c) ASSIGN GEOGRAPHICAL COORDINATES TO GRID POINT

325

FIGURE 2

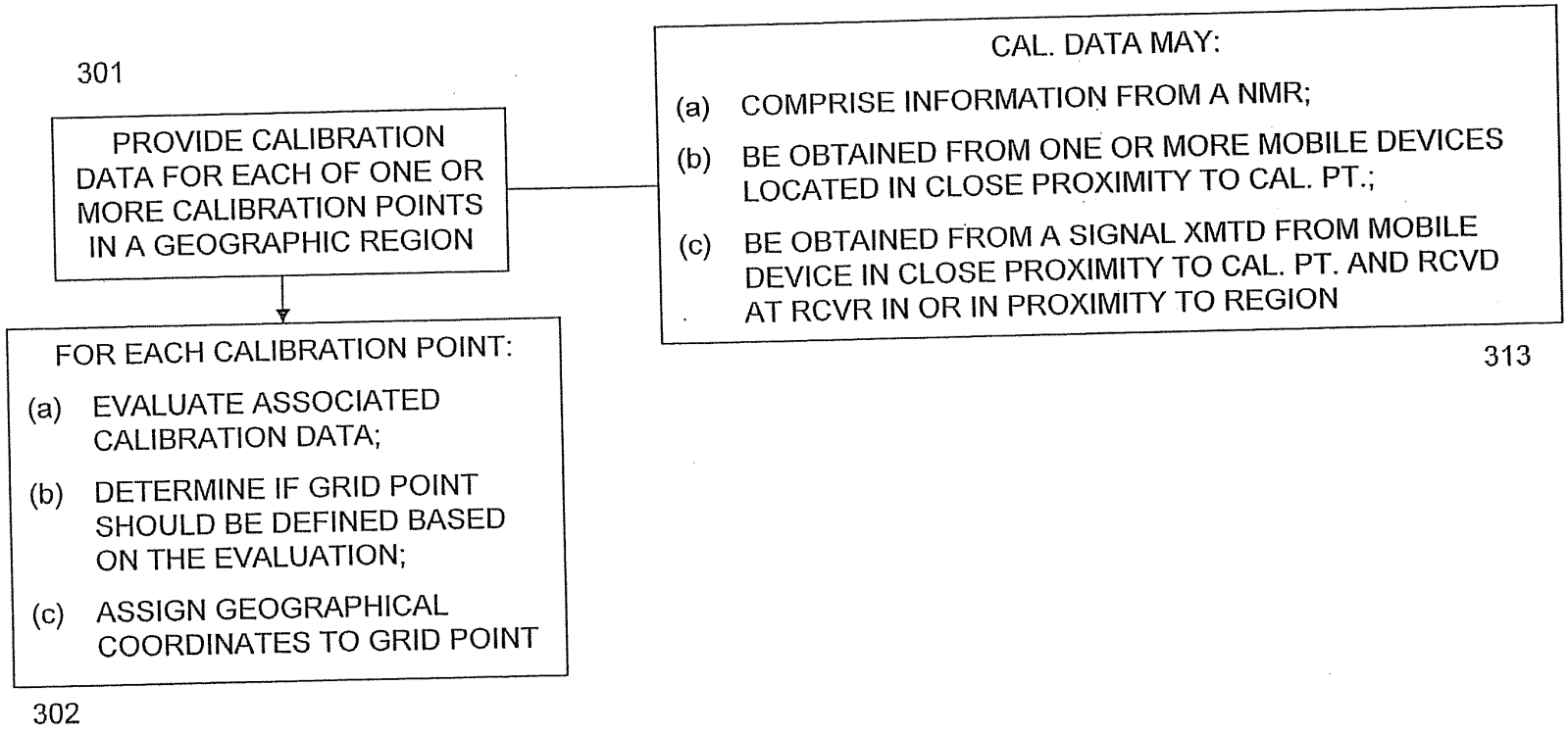

301
PROVIDE CALIBRATION DATA FOR EACH OF ONE OR MORE CALIBRATION POINTS IN A GEOGRAPHIC REGION
CAL. DATA MAY:
(a) COMPRISE INFORMATION FROM A NMR;
(b) BE OBTAINED FROM ONE OR MORE MOBILE DEVICES LOCATED IN CLOSE PROXIMITY TO CAL. PT.;
(c) BE OBTAINED FROM A SIGNAL XMTD FROM MOBILE DEVICE IN CLOSE PROXIMITY TO CAL. PT. AND RCVD AT RCVR IN OR IN PROXIMITY TO REGION
313
FOR EACH CALIBRATION POINT:
(a) EVALUATE ASSOCIATED CALIBRATION DATA;
(b) DETERMINE IF GRID POINT SHOULD BE DEFINED BASED ON THE EVALUATION;
(c) ASSIGN GEOGRAPHICAL COORDINATES TO GRID POINT
302
326

FIGURE 3

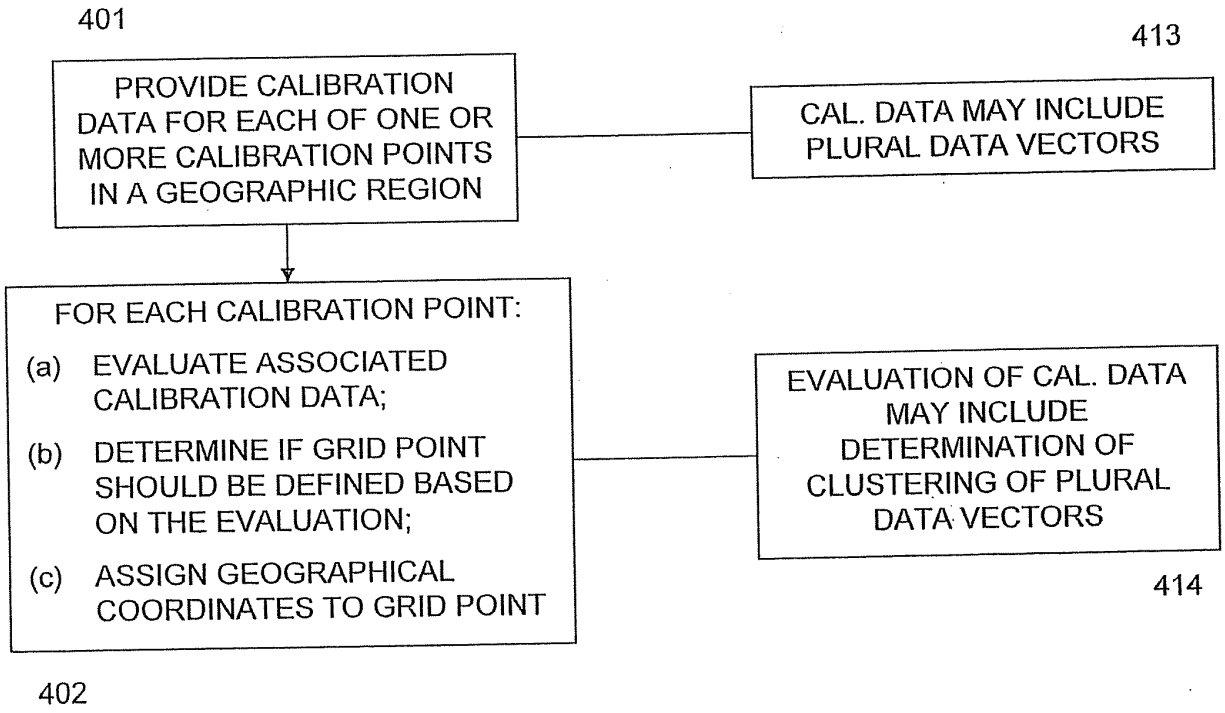

401
PROVIDE CALIBRATION DATA FOR EACH OF ONE OR MORE CALIBRATION POINTS IN A GEOGRAPHIC REGION
413
CAL. DATA MAY INCLUDE PLURAL DATA VECTORS
FOR EACH CALIBRATION POINT:
(a) EVALUATE ASSOCIATED CALIBRATION DATA;
(b) DETERMINE IF GRID POINT SHOULD BE DEFINED BASED ON THE EVALUATION;
(c) ASSIGN GEOGRAPHICAL COORDINATES TO GRID POINT
EVALUATION OF CAL. DATA MAY INCLUDE DETERMINATION OF CLUSTERING OF PLURAL DATA VECTORS
414
402

FIGURE 4

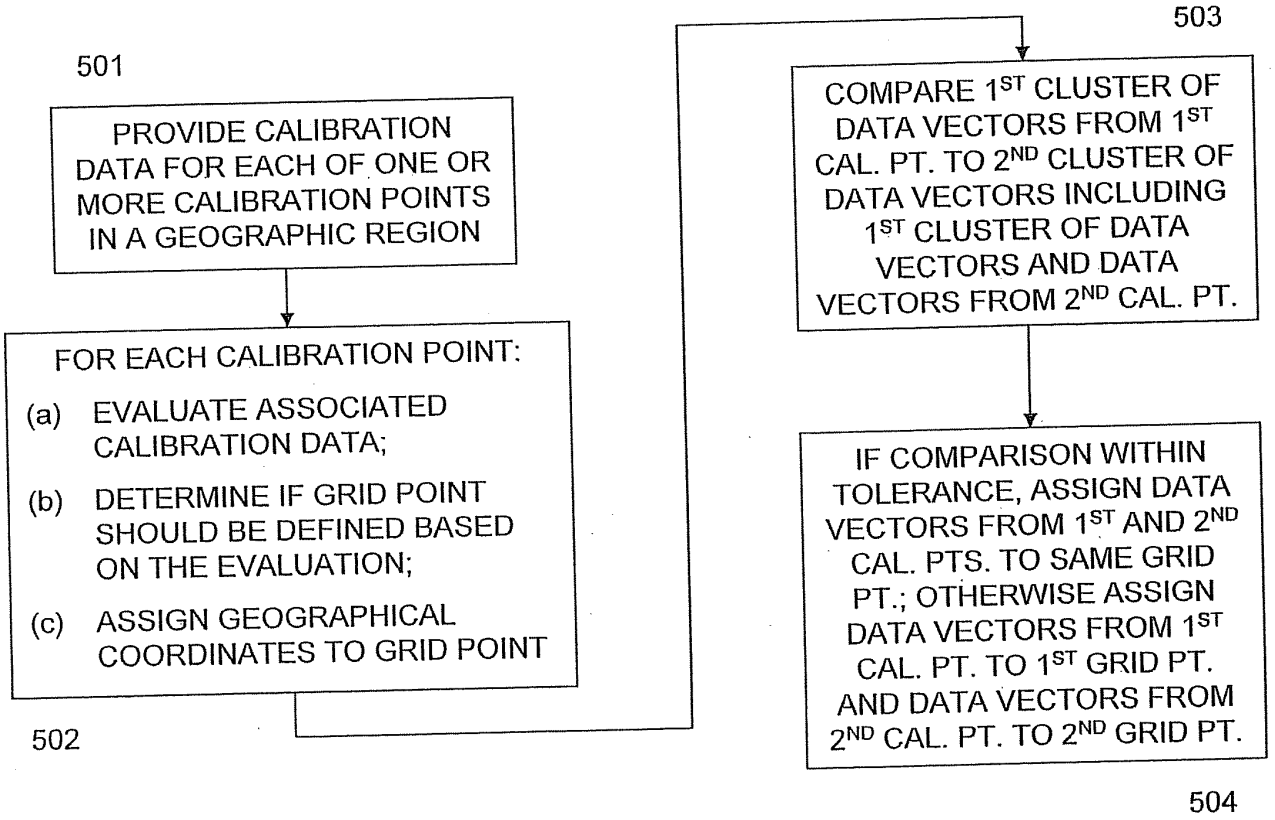

501
PROVIDE CALIBRATION DATA FOR EACH OF ONE OR MORE CALIBRATION POINTS IN A GEOGRAPHIC REGION
FOR EACH CALIBRATION POINT:
(a) EVALUATE ASSOCIATED CALIBRATION DATA;
(b) DETERMINE IF GRID POINT SHOULD BE DEFINED BASED ON THE EVALUATION;
(c) ASSIGN GEOGRAPHICAL COORDINATES TO GRID POINT
502
503
COMPARE 1ST CLUSTER OF DATA VECTORS FROM 1ST CAL. PT. TO 2ND CLUSTER OF DATA VECTORS INCLUDING 1ST CLUSTER OF DATA VECTORS AND DATA VECTORS FROM 2ND CAL. PT.
IF COMPARISON WITHIN TOLERANCE, ASSIGN DATA VECTORS FROM 1ST AND 2ND CAL. PTS. TO SAME GRID PT.; OTHERWISE ASSIGN DATA VECTORS FROM 1ST CAL. PT. TO 1ST GRID PT. AND DATA VECTORS FROM 2ND CAL. PT. TO 2ND GRID PT.
504

FIGURE 5

328

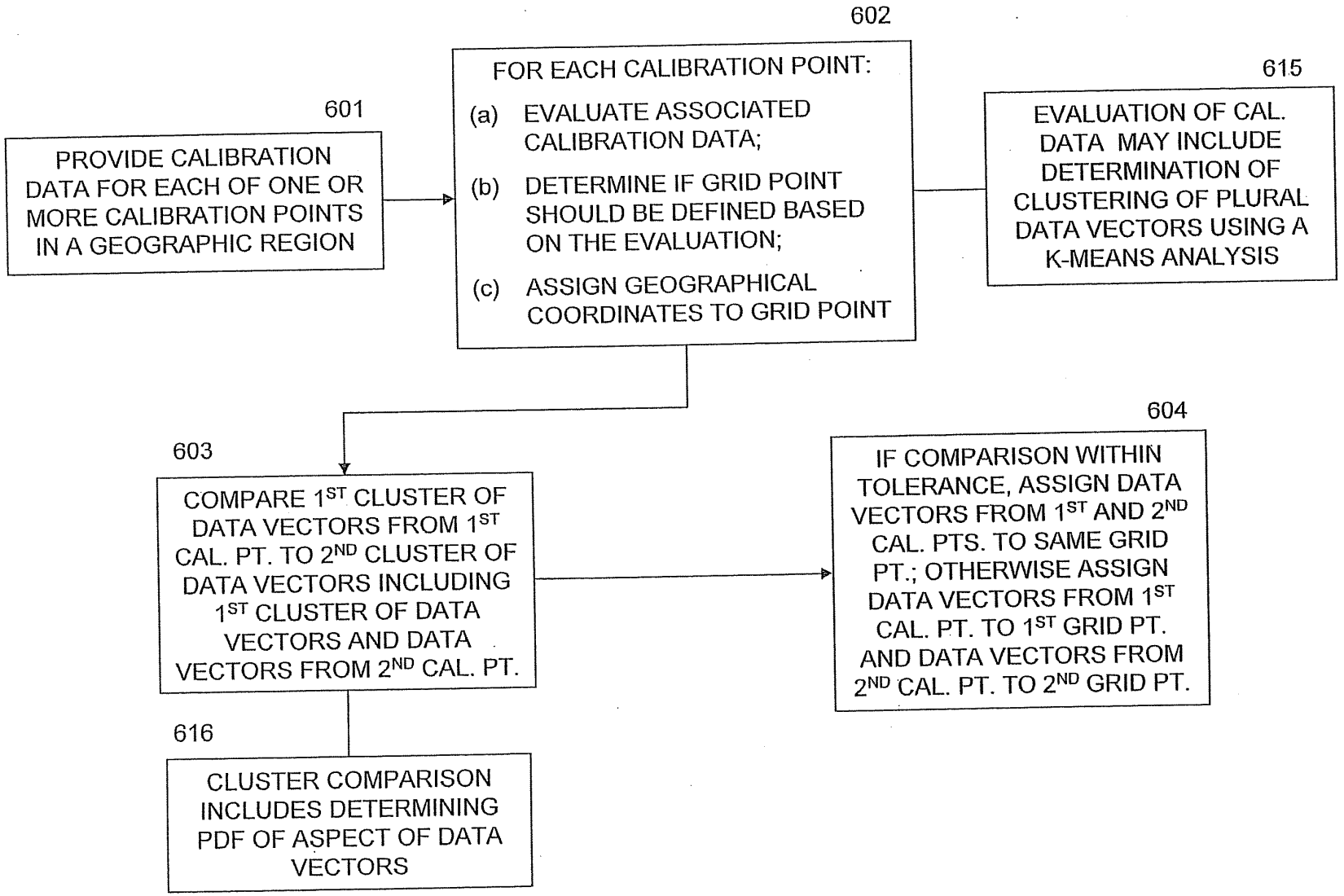
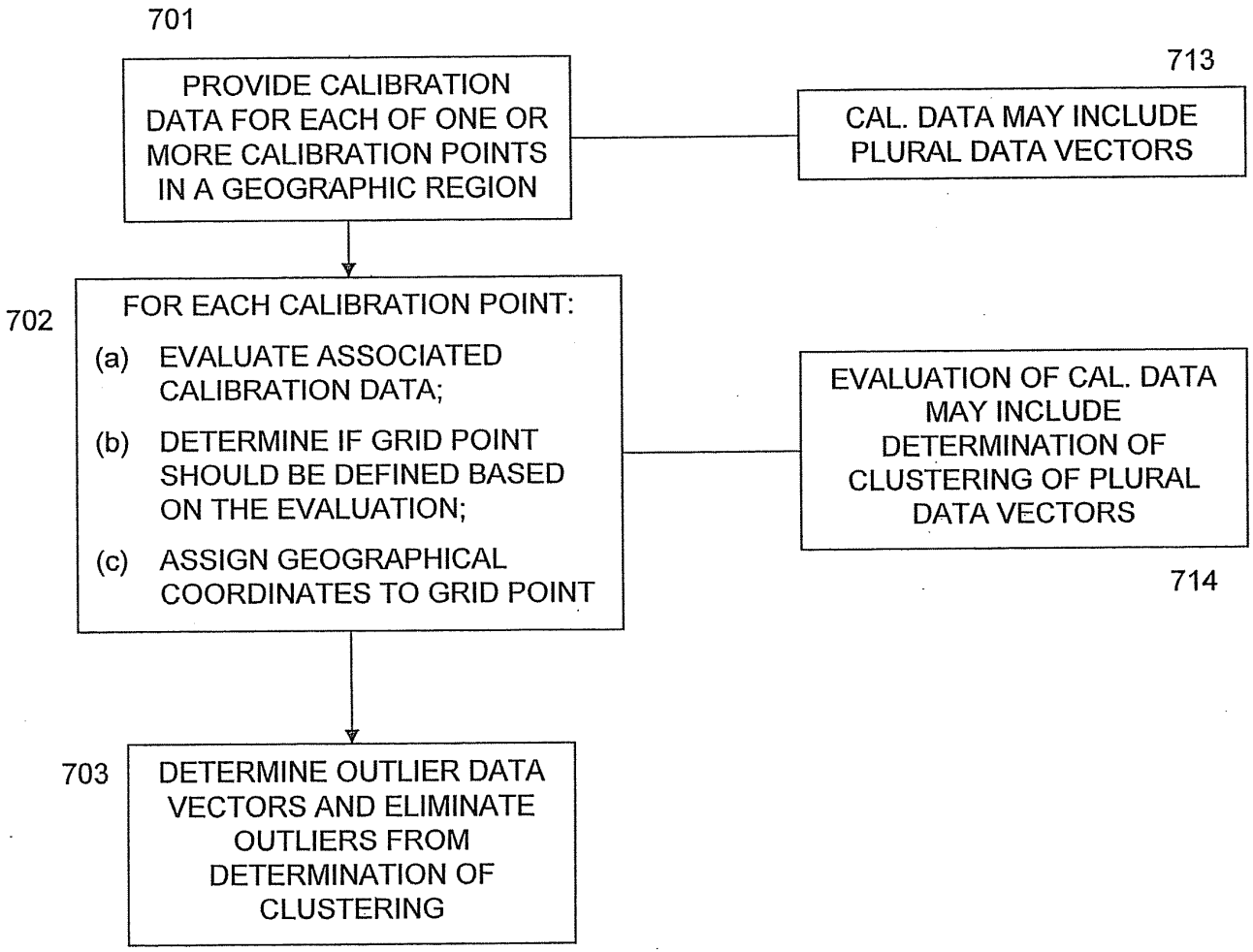

601
PROVIDE CALIBRATION DATA FOR EACH OF ONE OR MORE CALIBRATION POINTS IN A GEOGRAPHIC REGION
602
FOR EACH CALIBRATION POINT:
(a) EVALUATE ASSOCIATED CALIBRATION DATA;
(b) DETERMINE IF GRID POINT SHOULD BE DEFINED BASED ON THE EVALUATION;
(c) ASSIGN GEOGRAPHICAL COORDINATES TO GRID POINT
615
EVALUATION OF CAL. DATA MAY INCLUDE DETERMINATION OF CLUSTERING OF PLURAL DATA VECTORS USING A K-MEANS ANALYSIS
603
COMPARE 1ST CLUSTER OF DATA VECTORS FROM 1ST CAL. PT. TO 2ND CLUSTER OF DATA VECTORS INCLUDING 1ST CLUSTER OF DATA VECTORS AND DATA VECTORS FROM 2ND CAL. PT.
604
IF COMPARISON WITHIN TOLERANCE, ASSIGN DATA VECTORS FROM 1ST AND 2ND CAL. PTS. TO SAME GRID PT.; OTHERWISE ASSIGN DATA VECTORS FROM 1ST CAL. PT. TO 1ST GRID PT. AND DATA VECTORS FROM 2ND CAL. PT. TO 2ND GRID PT.
616
CLUSTER COMPARISON INCLUDES DETERMINING PDF OF ASPECT OF DATA VECTORS

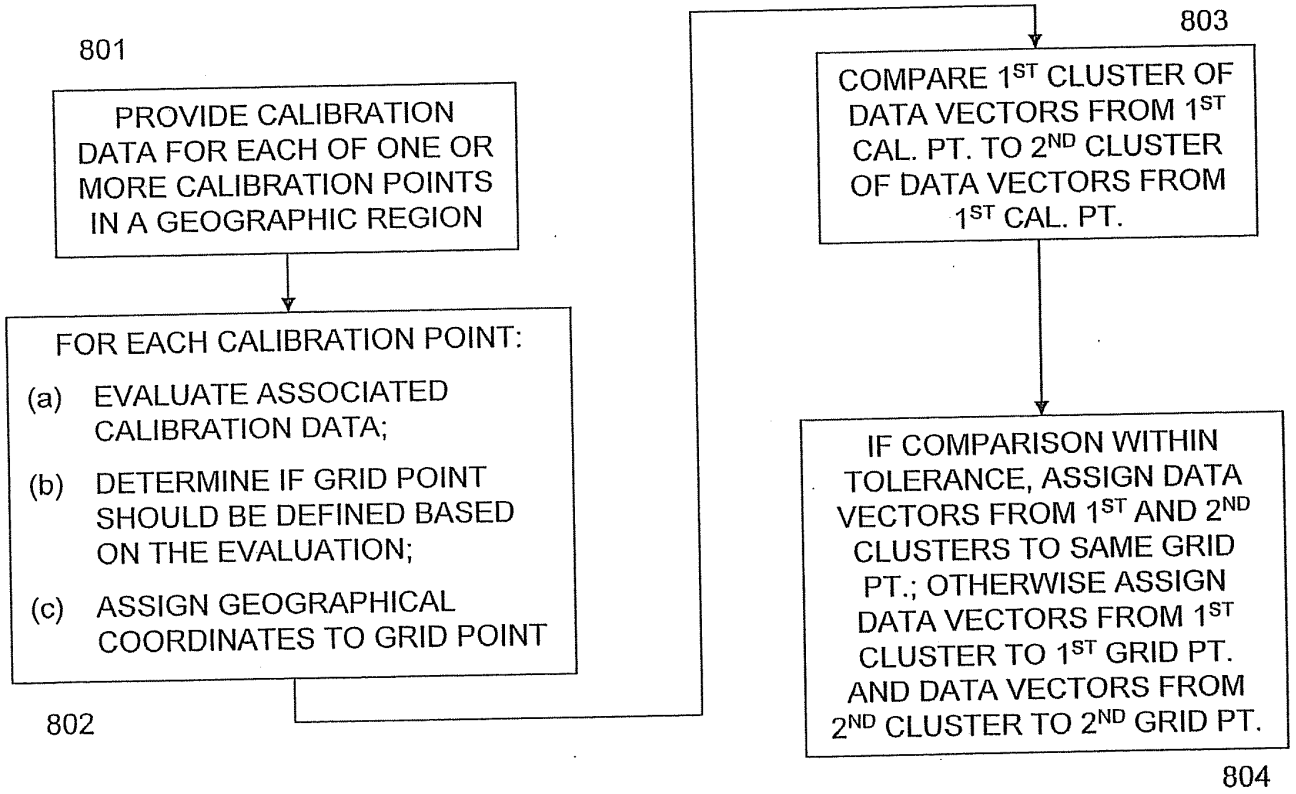
FIGURE 6

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701
PROVIDE CALIBRATION DATA FOR EACH OF ONE OR MORE CALIBRATION POINTS IN A GEOGRAPHIC REGION
713
CAL. DATA MAY INCLUDE PLURAL DATA VECTORS
702
FOR EACH CALIBRATION POINT:
(a) EVALUATE ASSOCIATED CALIBRATION DATA;
(b) DETERMINE IF GRID POINT SHOULD BE DEFINED BASED ON THE EVALUATION;
(c) ASSIGN GEOGRAPHICAL COORDINATES TO GRID POINT
EVALUATION OF CAL. DATA MAY INCLUDE DETERMINATION OF CLUSTERING OF PLURAL DATA VECTORS
714
703
DETERMINE OUTLIER DATA VECTORS AND ELIMINATE OUTLIERS FROM DETERMINATION OF CLUSTERING

330

FIGURE 7


801
PROVIDE CALIBRATION DATA FOR EACH OF ONE OR MORE CALIBRATION POINTS IN A GEOGRAPHIC REGION
FOR EACH CALIBRATION POINT:
(a) EVALUATE ASSOCIATED CALIBRATION DATA;
(b) DETERMINE IF GRID POINT SHOULD BE DEFINED BASED ON THE EVALUATION;
(c) ASSIGN GEOGRAPHICAL COORDINATES TO GRID POINT
802
803
COMPARE 1ST CLUSTER OF DATA VECTORS FROM 1ST CAL. PT. TO 2ND CLUSTER OF DATA VECTORS FROM 1ST CAL. PT.
IF COMPARISON WITHIN TOLERANCE, ASSIGN DATA VECTORS FROM 1ST AND 2ND CLUSTERS TO SAME GRID PT.; OTHERWISE ASSIGN DATA VECTORS FROM 1ST CLUSTER TO 1ST GRID PT. AND DATA VECTORS FROM 2ND CLUSTER TO 2ND GRID PT.
804

331

FIGURE 8

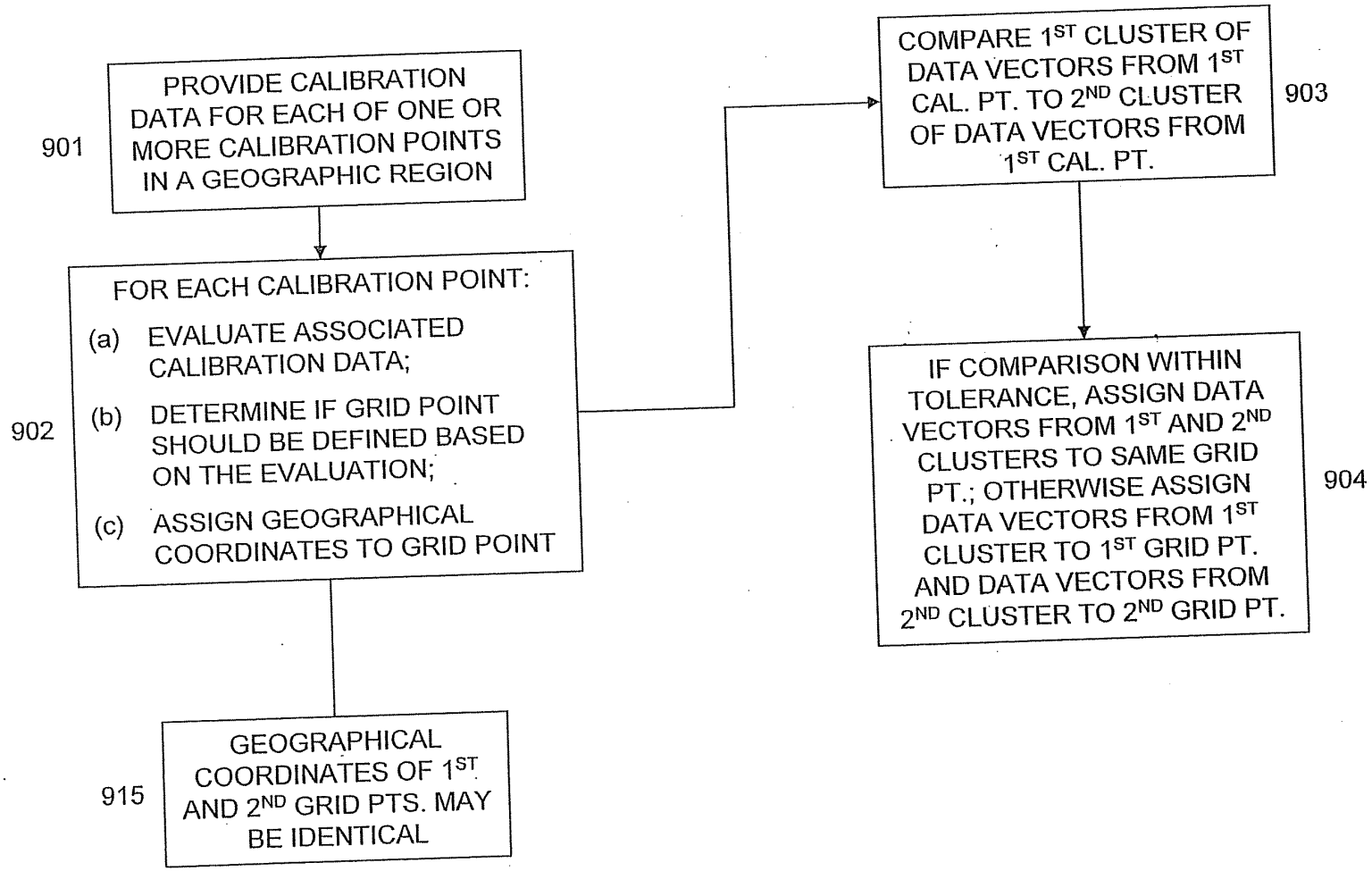
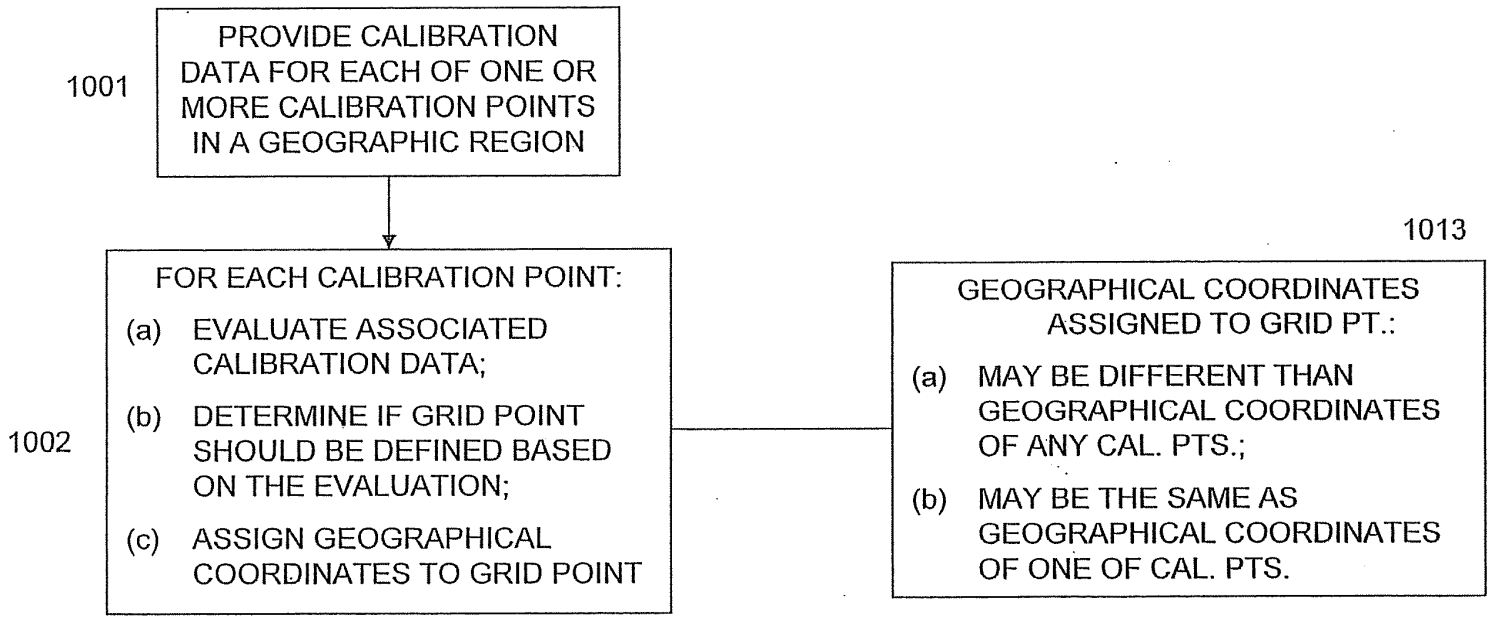
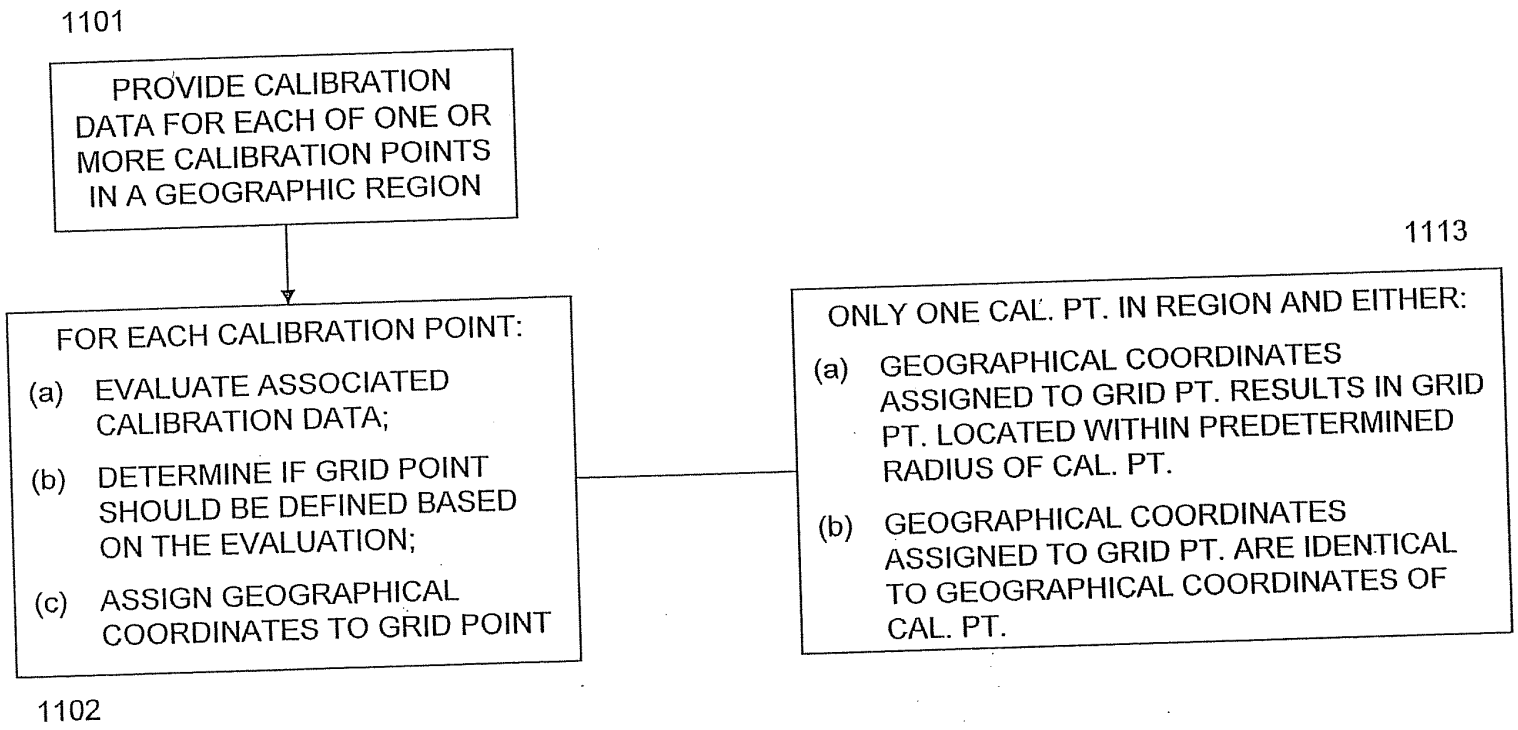

PROVIDE CALIBRATION DATA FOR EACH OF ONE OR MORE CALIBRATION POINTS IN A GEOGRAPHIC REGION
901
FOR EACH CALIBRATION POINT:
(a) EVALUATE ASSOCIATED CALIBRATION DATA;
(b) DETERMINE IF GRID POINT SHOULD BE DEFINED BASED ON THE EVALUATION;
(c) ASSIGN GEOGRAPHICAL COORDINATES TO GRID POINT
902
COMPARE 1ST CLUSTER OF DATA VECTORS FROM 1ST CAL. PT. TO 2ND CLUSTER OF DATA VECTORS FROM 1ST CAL. PT.
903
IF COMPARISON WITHIN TOLERANCE, ASSIGN DATA VECTORS FROM 1ST AND 2ND CLUSTERS TO SAME GRID PT.; OTHERWISE ASSIGN DATA VECTORS FROM 1ST CLUSTER TO 1ST GRID PT. AND DATA VECTORS FROM 2ND CLUSTER TO 2ND GRID PT.
904
GEOGRAPHICAL COORDINATES OF 1ST AND 2ND GRID PTS. MAY BE IDENTICAL
915

FIGURE 9



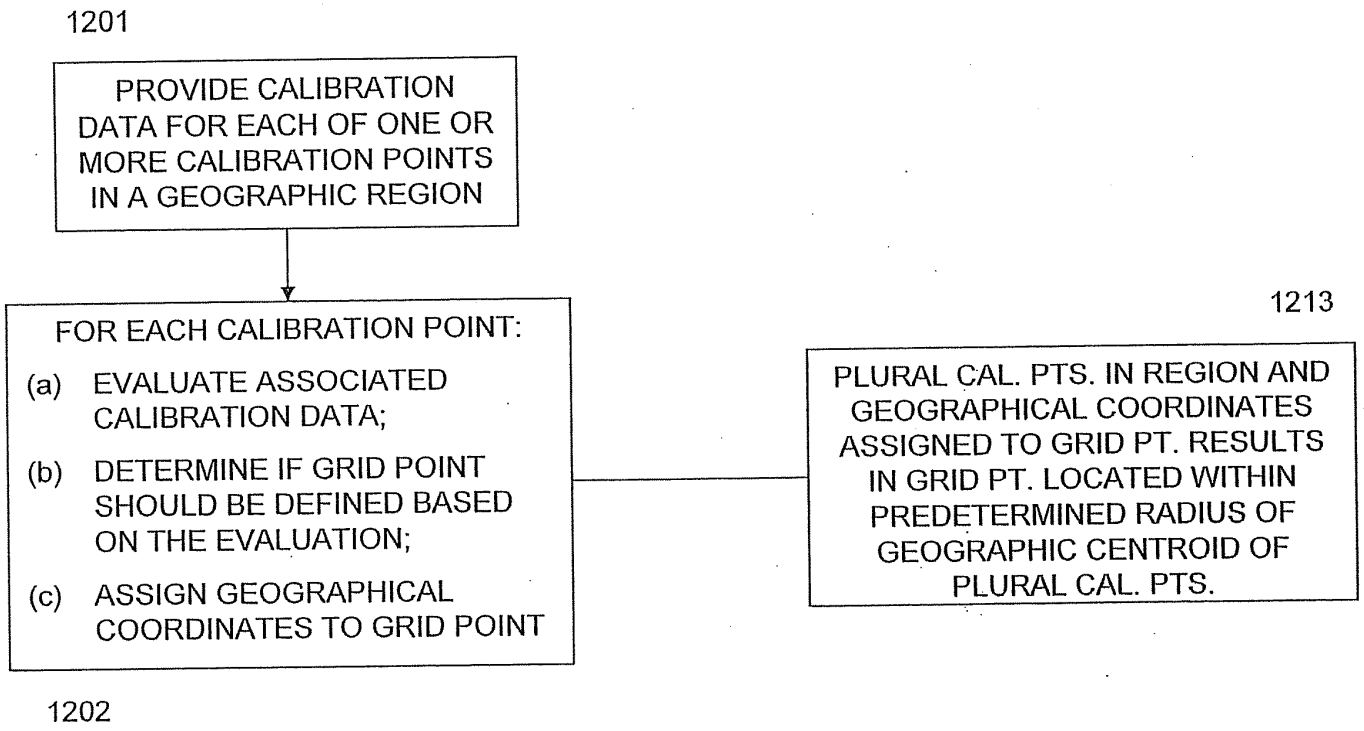
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FIGURE 10



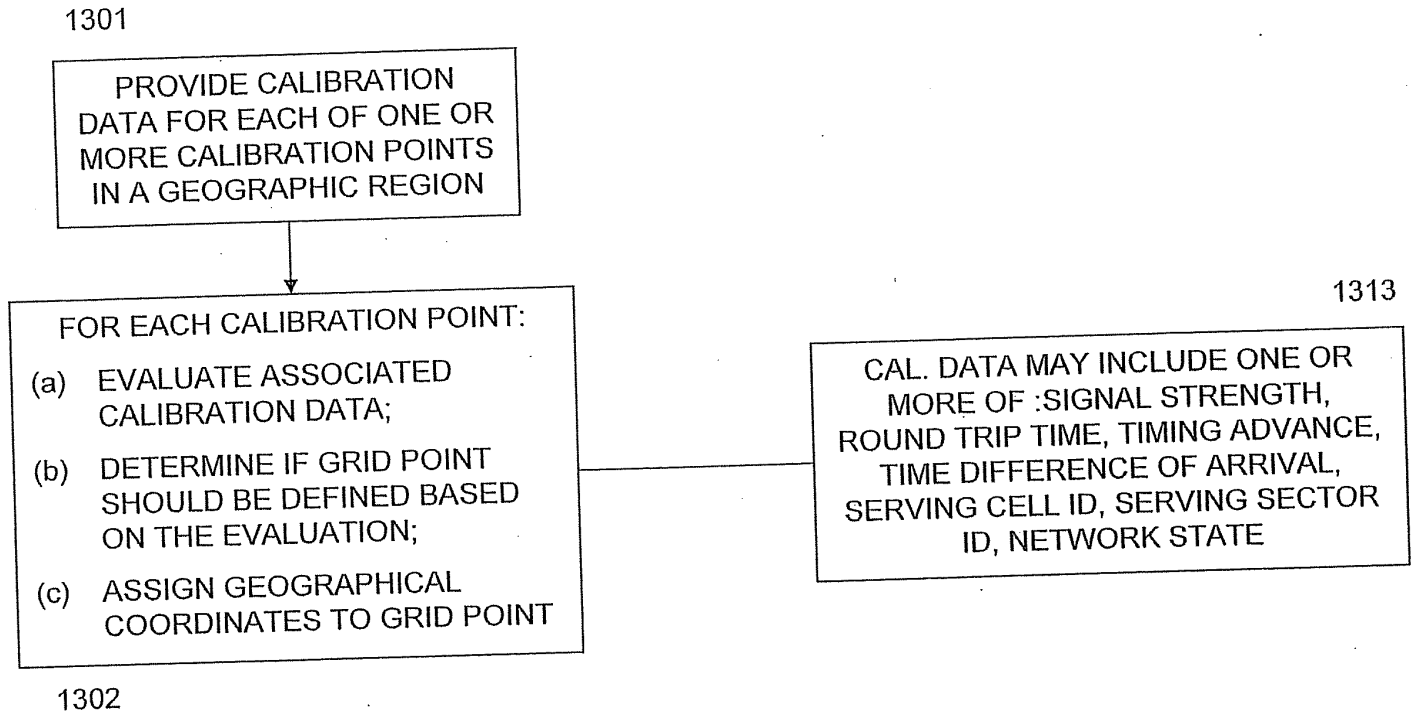
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FIGURE 11



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FIGURE 12



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FIGURE 13

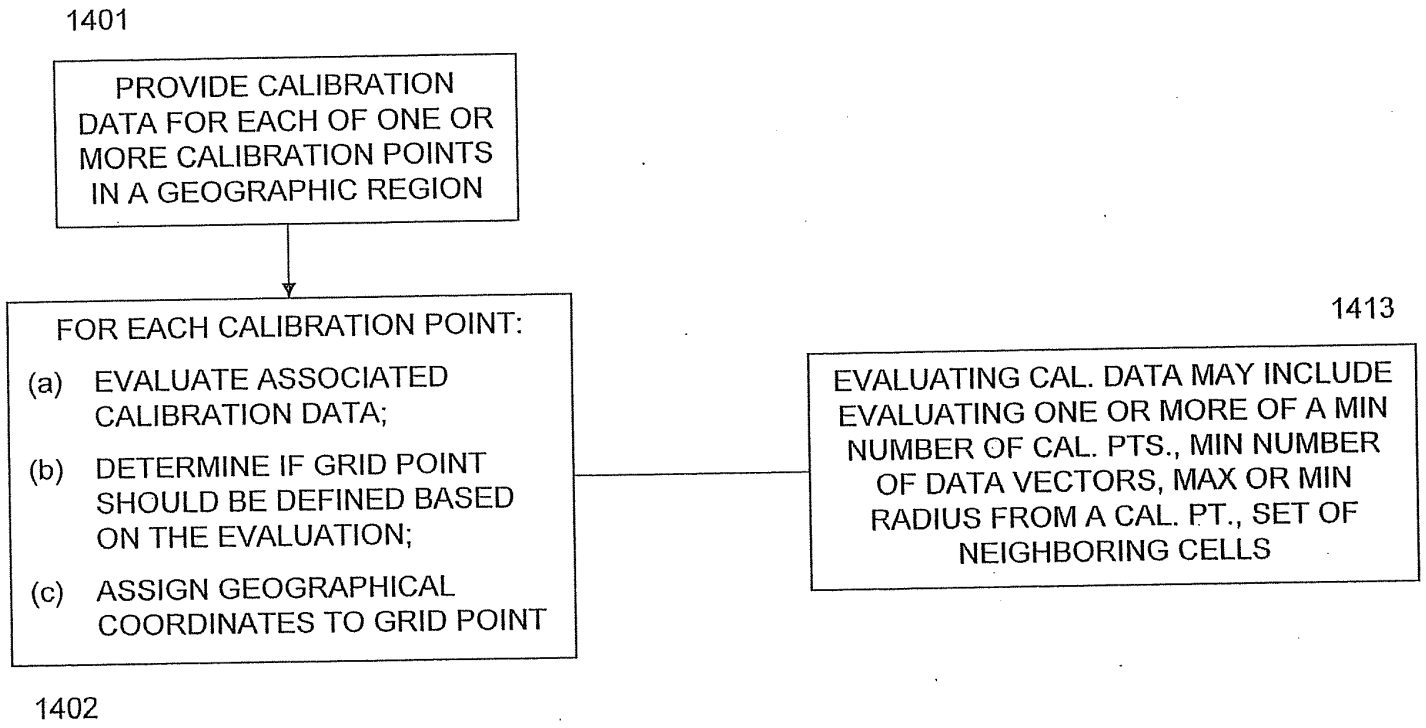

1401
PROVIDE CALIBRATION DATA FOR EACH OF ONE OR MORE CALIBRATION POINTS IN A GEOGRAPHIC REGION
FOR EACH CALIBRATION POINT:
(a) EVALUATE ASSOCIATED CALIBRATION DATA;
(b) DETERMINE IF GRID POINT SHOULD BE DEFINED BASED ON THE EVALUATION;
(c) ASSIGN GEOGRAPHICAL COORDINATES TO GRID POINT
1402
1413
EVALUATING CAL. DATA MAY INCLUDE EVALUATING ONE OR MORE OF A MIN NUMBER OF CAL. PTS., MIN NUMBER OF DATA VECTORS, MAX OR MIN RADIUS FROM A CAL. PT., SET OF NEIGHBORING CELLS

FIGURE 14

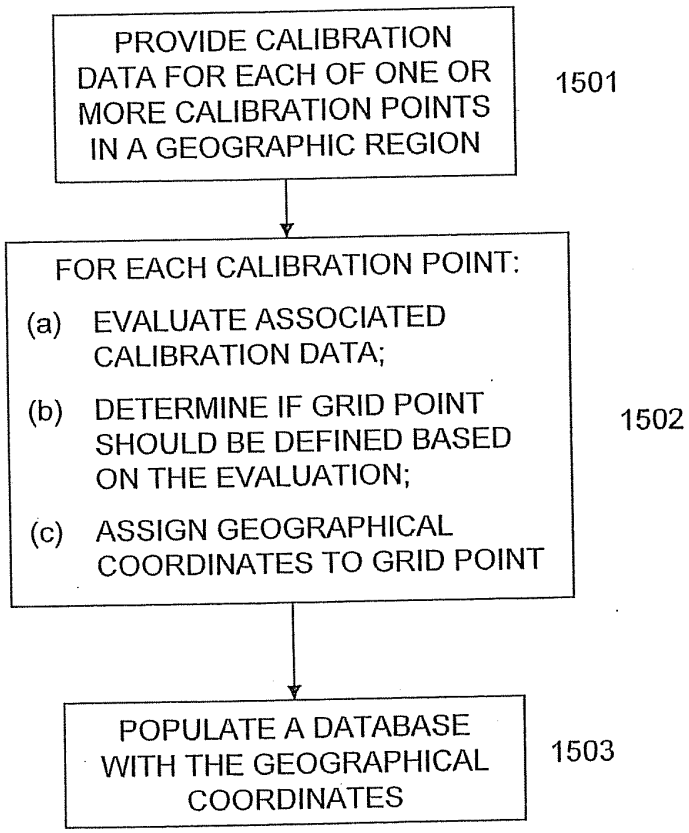


FIGURE 15

338

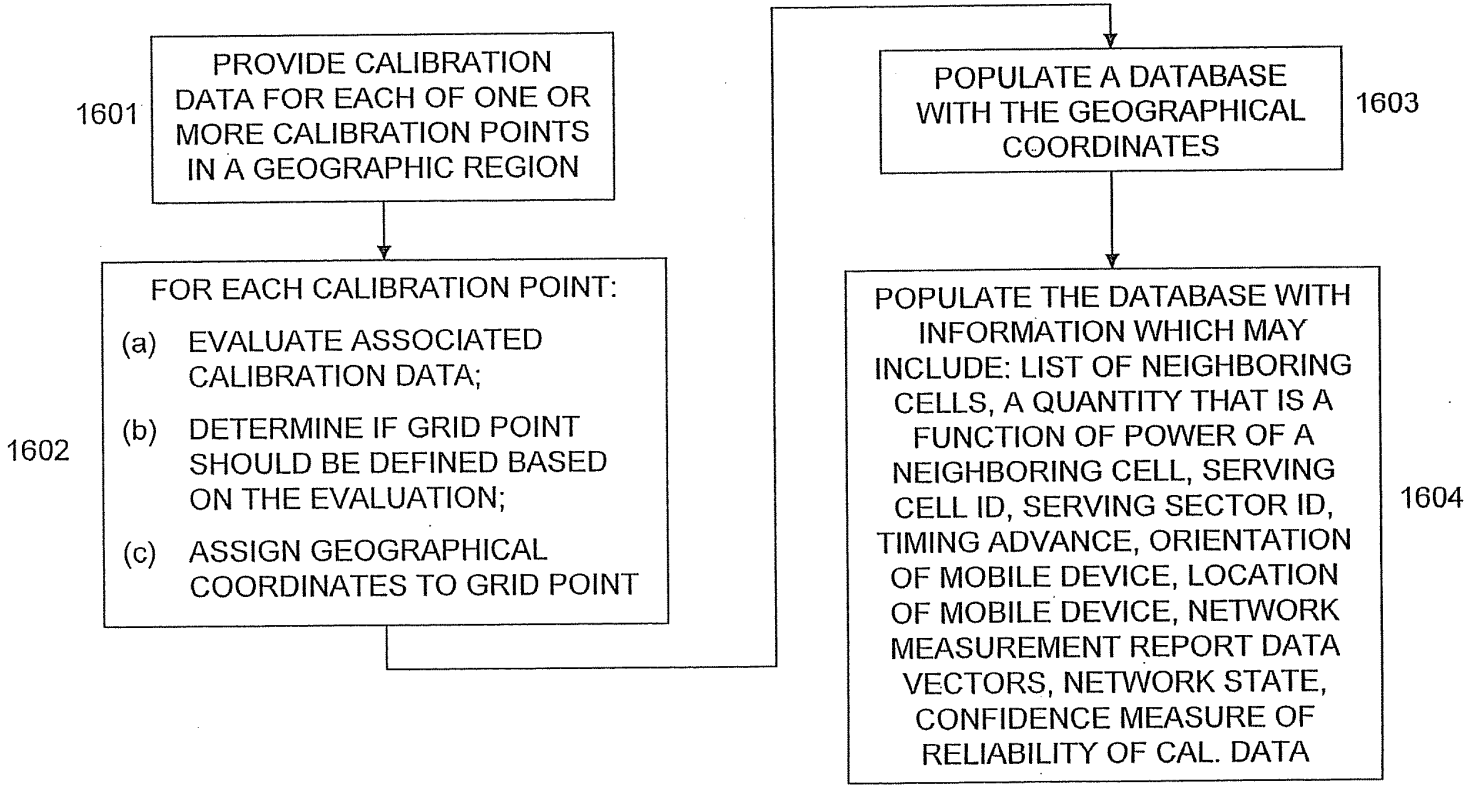
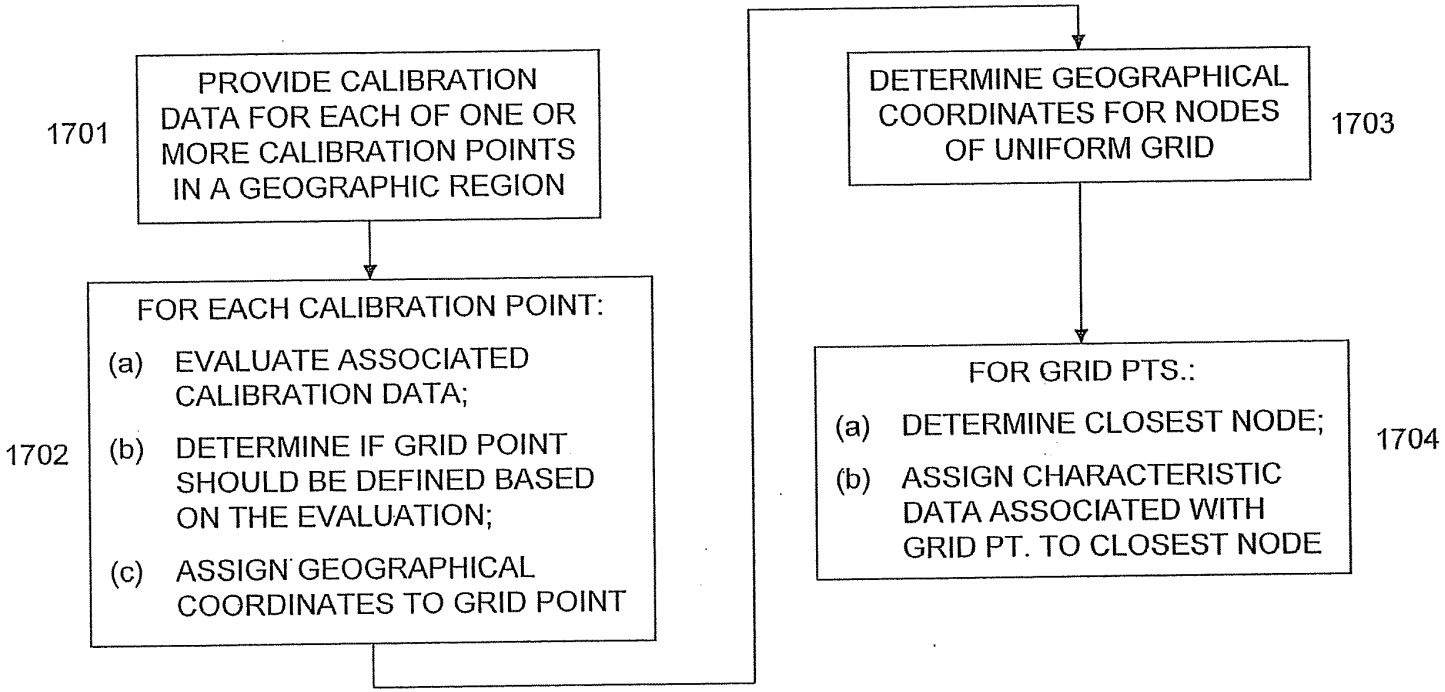

1601
PROVIDE CALIBRATION DATA FOR EACH OF ONE OR MORE CALIBRATION POINTS IN A GEOGRAPHIC REGION
1602
FOR EACH CALIBRATION POINT:
(a) EVALUATE ASSOCIATED CALIBRATION DATA;
(b) DETERMINE IF GRID POINT SHOULD BE DEFINED BASED ON THE EVALUATION;
(c) ASSIGN GEOGRAPHICAL COORDINATES TO GRID POINT
1603
POPULATE A DATABASE WITH THE GEOGRAPHICAL COORDINATES
1604
POPULATE THE DATABASE WITH INFORMATION WHICH MAY INCLUDE: LIST OF NEIGHBORING CELLS, A QUANTITY THAT IS A FUNCTION OF POWER OF A NEIGHBORING CELL, SERVING CELL ID, SERVING SECTOR ID, TIMING ADVANCE, ORIENTATION OF MOBILE DEVICE, LOCATION OF MOBILE DEVICE, NETWORK MEASUREMENT REPORT DATA VECTORS, NETWORK STATE, CONFIDENCE MEASURE OF RELIABILITY OF CAL. DATA

FIGURE 16



340

FIGURE 17

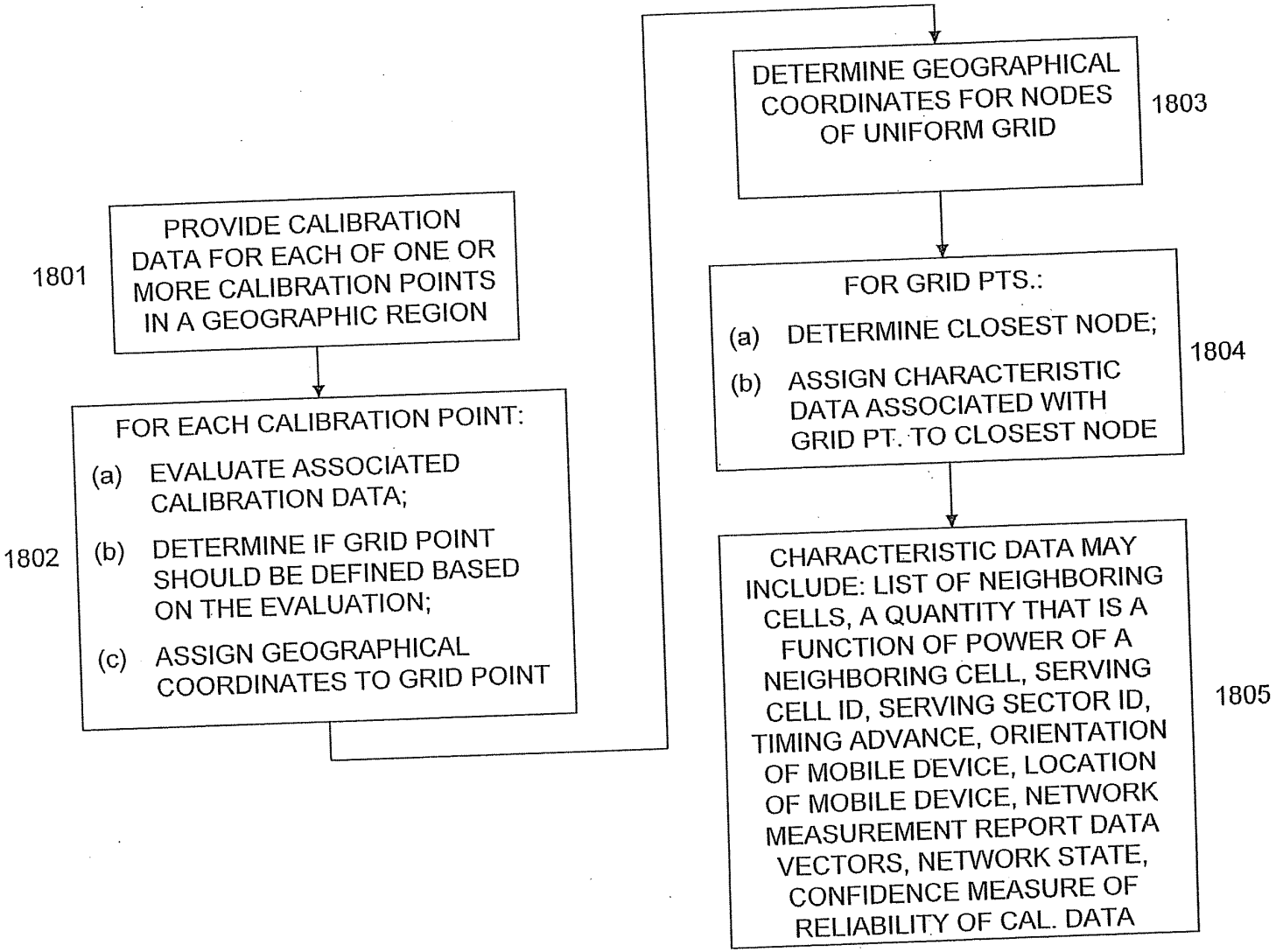
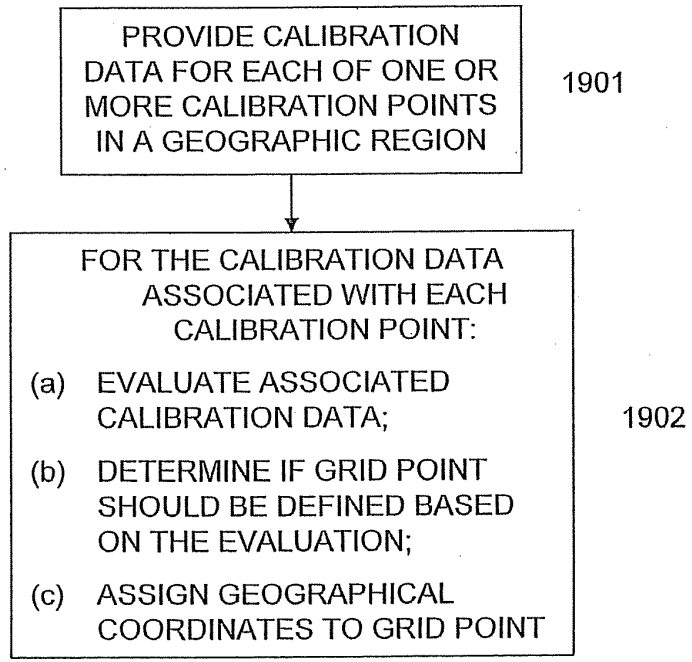

PROVIDE CALIBRATION DATA FOR EACH OF ONE OR MORE CALIBRATION POINTS IN A GEOGRAPHIC REGION
1801
FOR EACH CALIBRATION POINT:
(a) EVALUATE ASSOCIATED CALIBRATION DATA;
(b) DETERMINE IF GRID POINT SHOULD BE DEFINED BASED ON THE EVALUATION;
(c) ASSIGN GEOGRAPHICAL COORDINATES TO GRID POINT
1802
DETERMINE GEOGRAPHICAL COORDINATES FOR NODES OF UNIFORM GRID
1803
FOR GRID PTS.:
(a) DETERMINE CLOSEST NODE;
(b) ASSIGN CHARACTERISTIC DATA ASSOCIATED WITH GRID PT. TO CLOSEST NODE
1804
CHARACTERISTIC DATA MAY INCLUDE: LIST OF NEIGHBORING CELLS, A QUANTITY THAT IS A FUNCTION OF POWER OF A NEIGHBORING CELL, SERVING CELL ID, SERVING SECTOR ID, TIMING ADVANCE, ORIENTATION OF MOBILE DEVICE, LOCATION OF MOBILE DEVICE, NETWORK MEASUREMENT REPORT DATA VECTORS, NETWORK STATE, CONFIDENCE MEASURE OF RELIABILITY OF CAL. DATA
1805

FIGURE 18



342

FIGURE 19

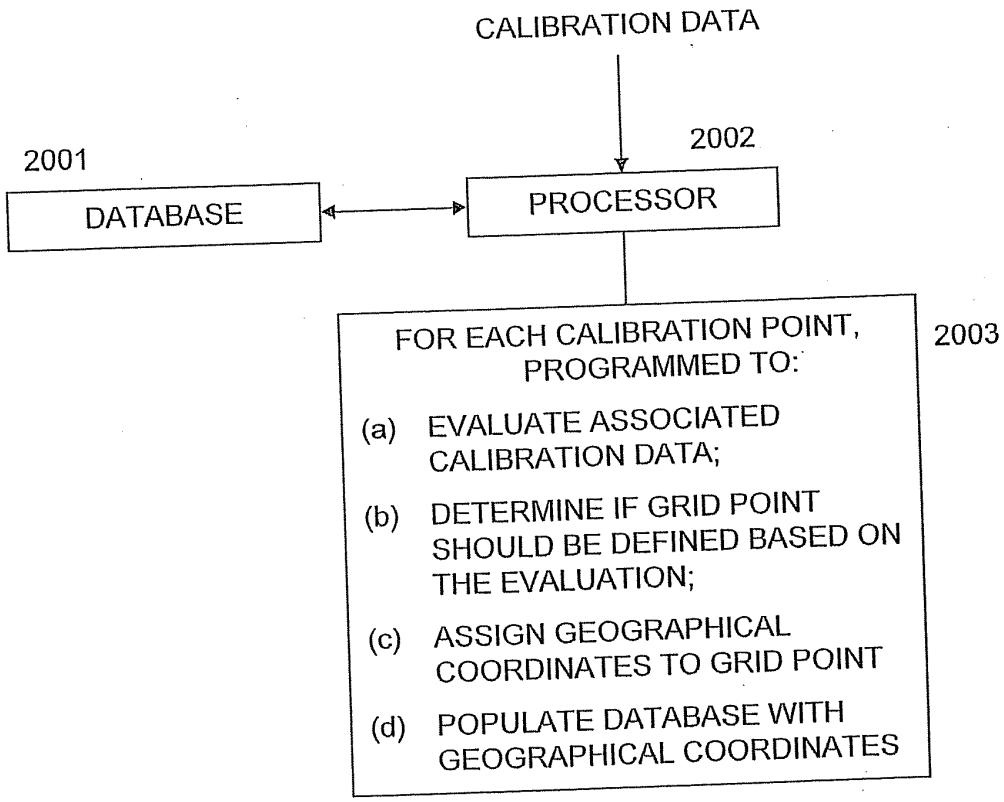
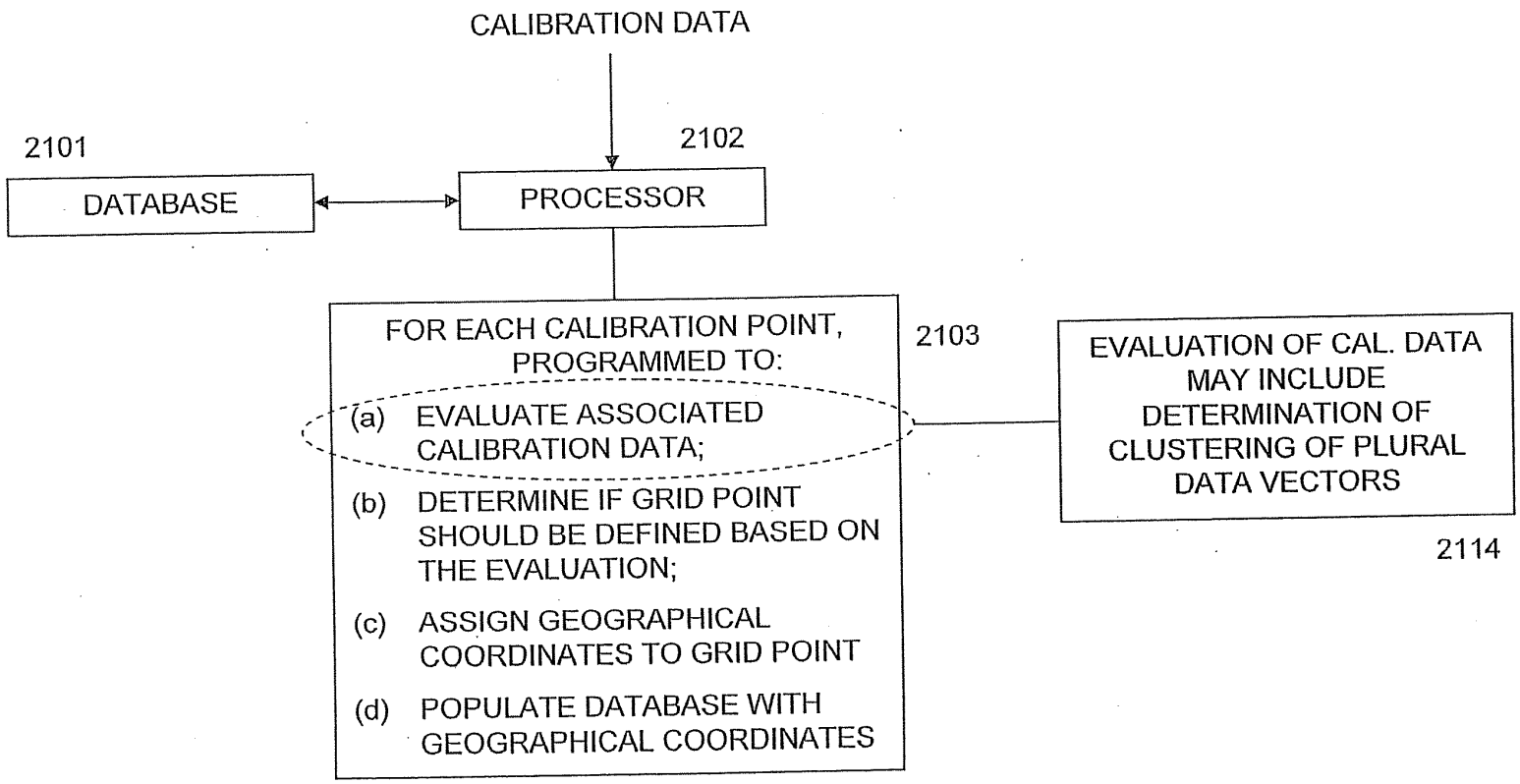

CALIBRATION DATA
2002
2001
DATABASE
PROCESSOR
FOR EACH CALIBRATION POINT, PROGRAMMED TO:
2003
(a) EVALUATE ASSOCIATED CALIBRATION DATA;
(b) DETERMINE IF GRID POINT SHOULD BE DEFINED BASED ON THE EVALUATION;
(c) ASSIGN GEOGRAPHICAL COORDINATES TO GRID POINT
(d) POPULATE DATABASE WITH GEOGRAPHICAL COORDINATES

FIGURE 20



344

FIGURE 21

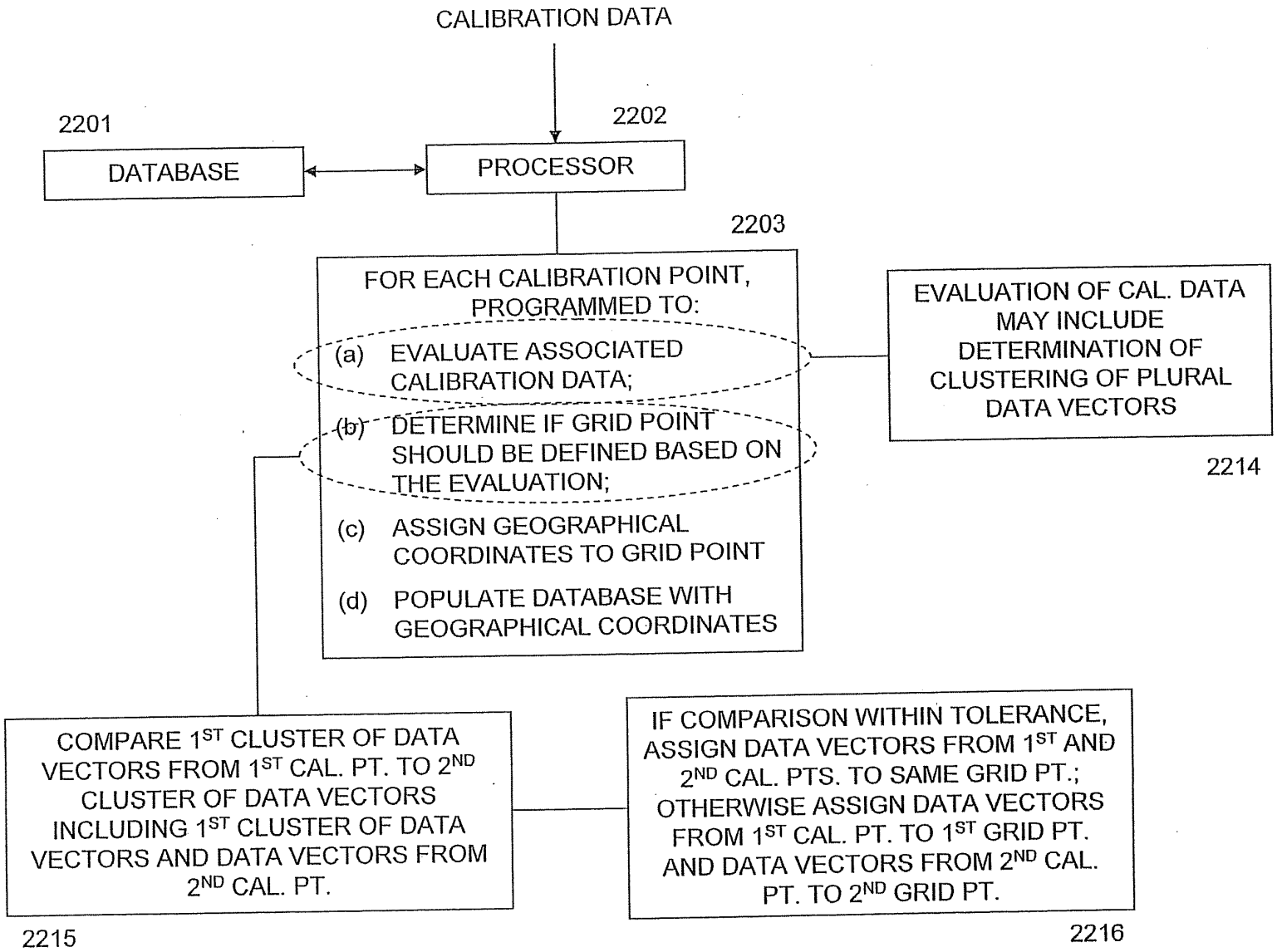


FIGURE 22

345

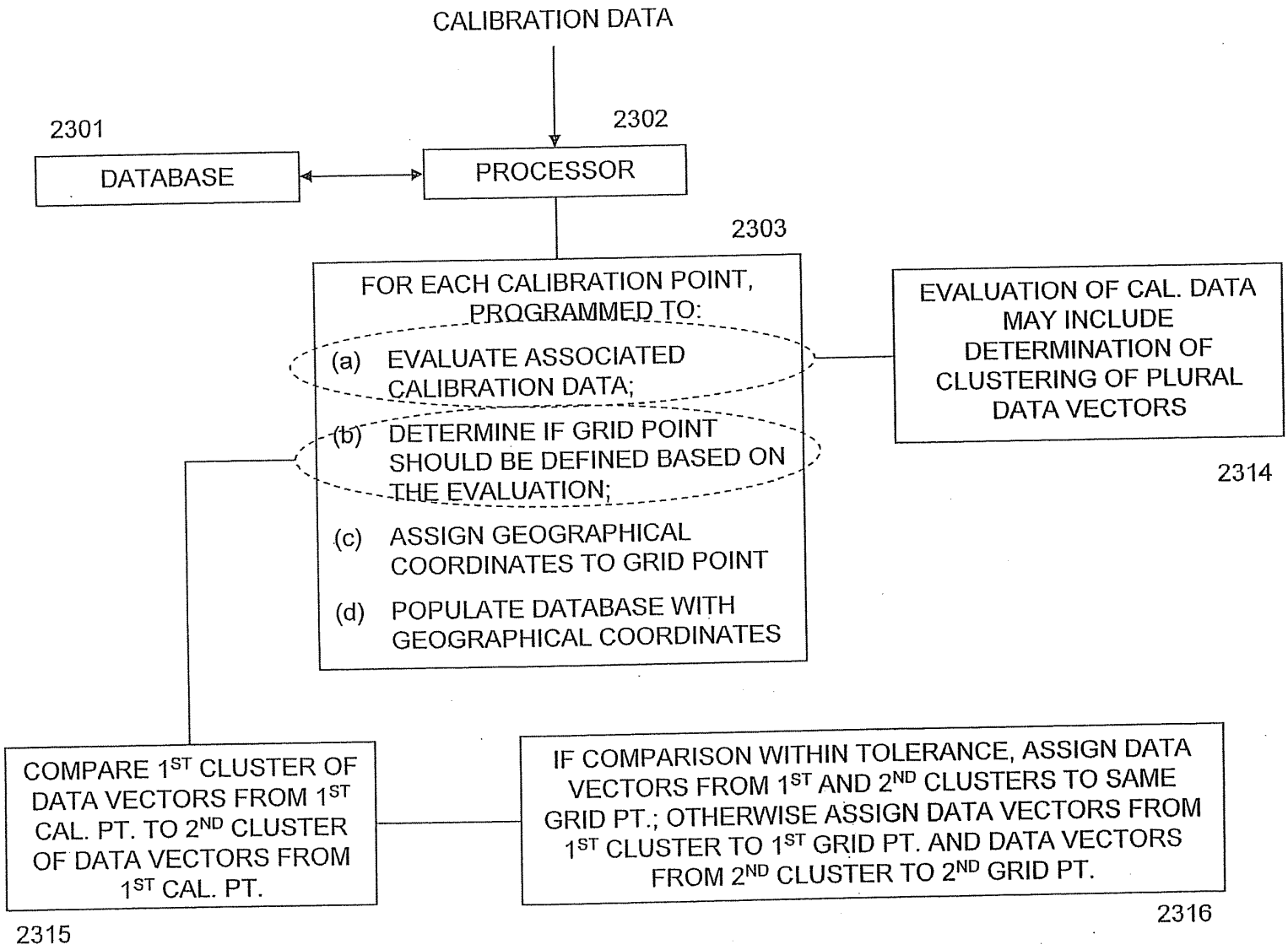


FIGURE 23

346

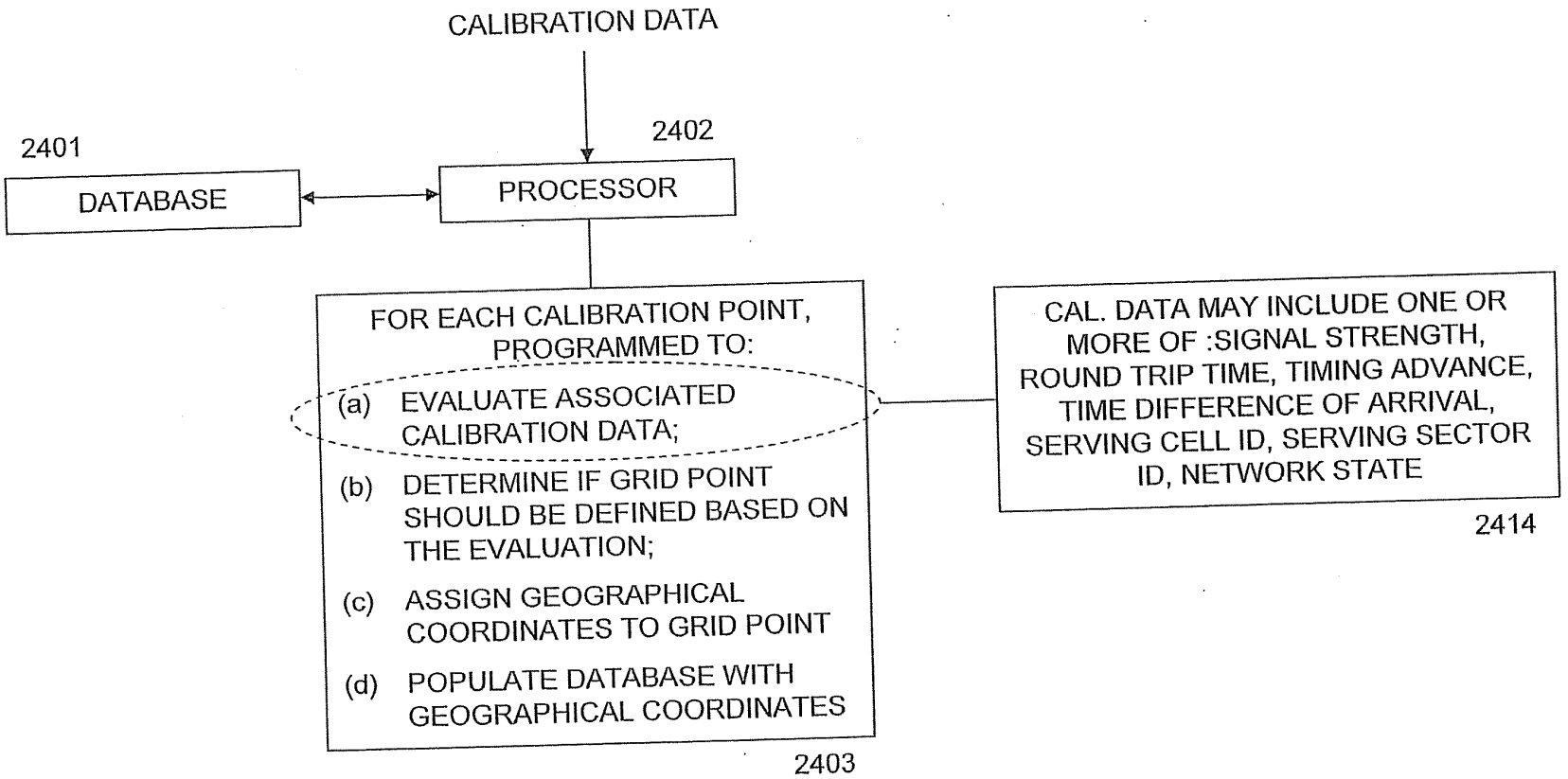

CALIBRATION DATA
2401
2402
DATABASE
PROCESSOR
FOR EACH CALIBRATION POINT, PROGRAMMED TO:
(a) EVALUATE ASSOCIATED CALIBRATION DATA;
(b) DETERMINE IF GRID POINT SHOULD BE DEFINED BASED ON THE EVALUATION;
(c) ASSIGN GEOGRAPHICAL COORDINATES TO GRID POINT
(d) POPULATE DATABASE WITH GEOGRAPHICAL COORDINATES
2403
CAL. DATA MAY INCLUDE ONE OR MORE OF :SIGNAL STRENGTH, ROUND TRIP TIME, TIMING ADVANCE, TIME DIFFERENCE OF ARRIVAL, SERVING CELL ID, SERVING SECTOR ID, NETWORK STATE
2414

FIGURE 24

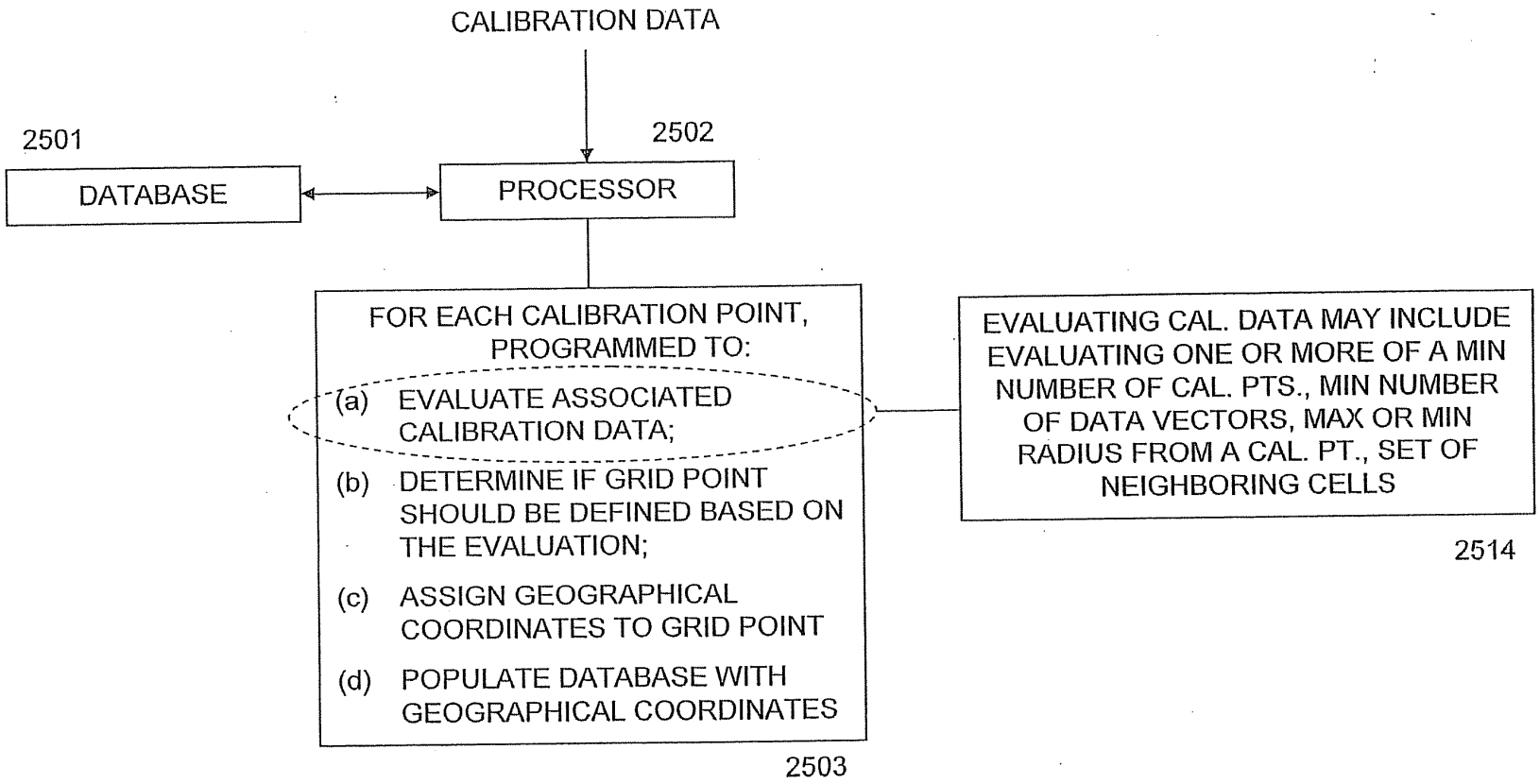

CALIBRATION DATA
2501
2502
DATABASE
PROCESSOR
FOR EACH CALIBRATION POINT, PROGRAMMED TO:
(a) EVALUATE ASSOCIATED CALIBRATION DATA;
(b) DETERMINE IF GRID POINT SHOULD BE DEFINED BASED ON THE EVALUATION;
(c) ASSIGN GEOGRAPHICAL COORDINATES TO GRID POINT
(d) POPULATE DATABASE WITH GEOGRAPHICAL COORDINATES
2503
EVALUATING CAL. DATA MAY INCLUDE EVALUATING ONE OR MORE OF A MIN NUMBER OF CAL. PTS., MIN NUMBER OF DATA VECTORS, MAX OR MIN RADIUS FROM A CAL. PT., SET OF NEIGHBORING CELLS
2514

FIGURE 25

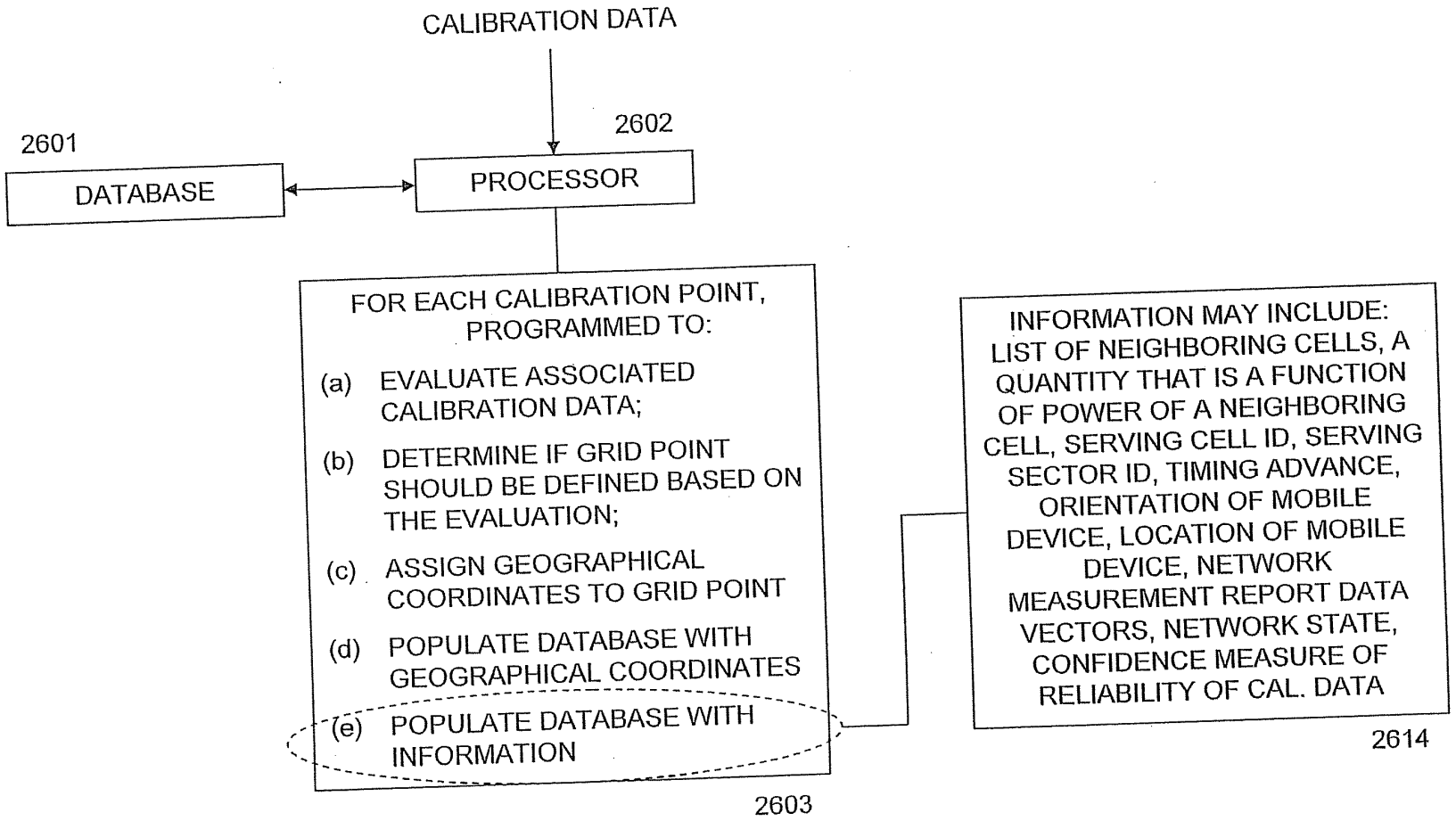

CALIBRATION DATA
2602
2601
DATABASE
PROCESSOR
FOR EACH CALIBRATION POINT, PROGRAMMED TO:
(a) EVALUATE ASSOCIATED CALIBRATION DATA;
(b) DETERMINE IF GRID POINT SHOULD BE DEFINED BASED ON THE EVALUATION;
(c) ASSIGN GEOGRAPHICAL COORDINATES TO GRID POINT
(d) POPULATE DATABASE WITH GEOGRAPHICAL COORDINATES
(e) POPULATE DATABASE WITH INFORMATION
2603
INFORMATION MAY INCLUDE: LIST OF NEIGHBORING CELLS, A QUANTITY THAT IS A FUNCTION OF POWER OF A NEIGHBORING CELL, SERVING CELL ID, SERVING SECTOR ID, TIMING ADVANCE, ORIENTATION OF MOBILE DEVICE, LOCATION OF MOBILE DEVICE, NETWORK MEASUREMENT REPORT DATA VECTORS, NETWORK STATE, CONFIDENCE MEASURE OF RELIABILITY OF CAL. DATA
2614

FIGURE 26

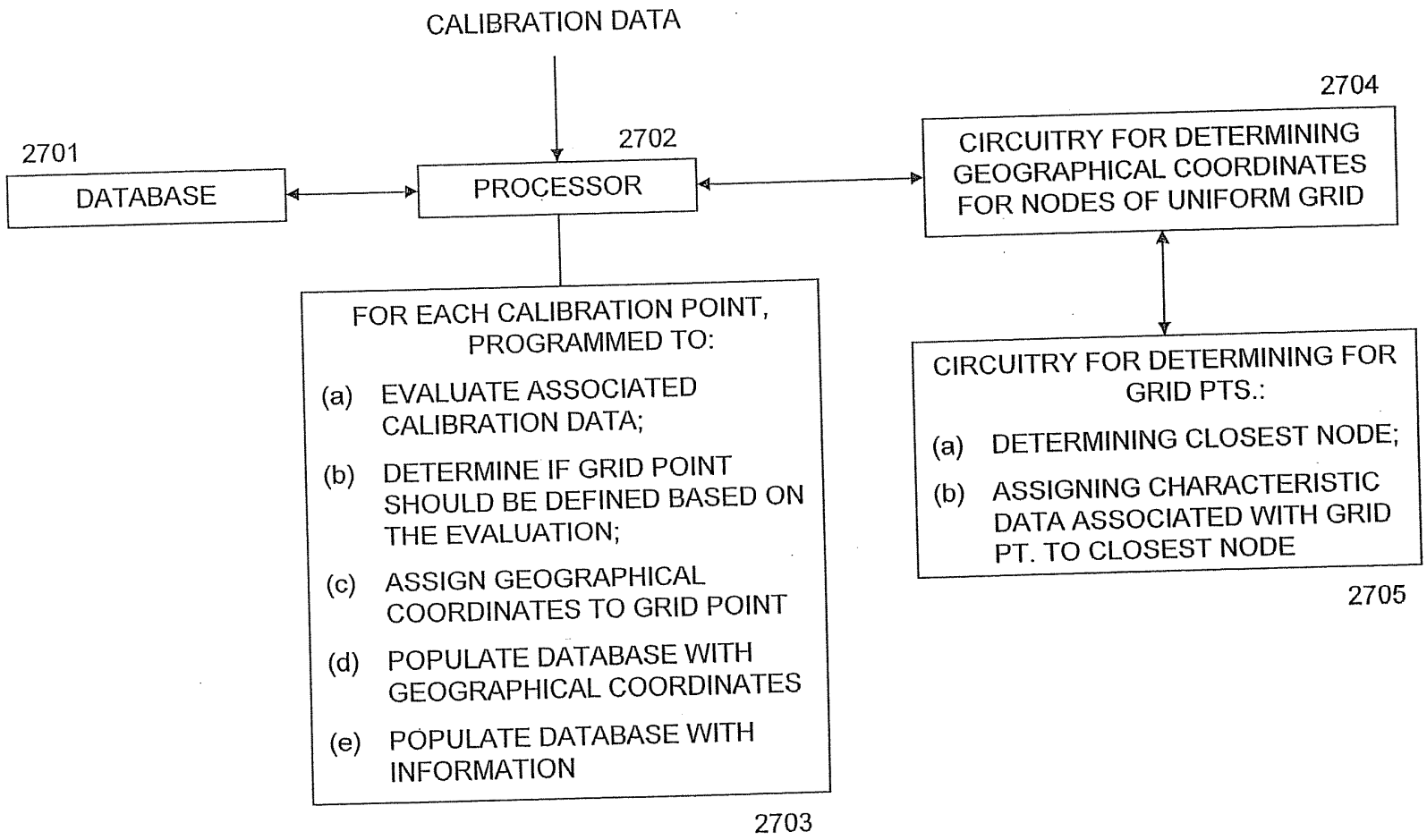

CALIBRATION DATA
2701
DATABASE
2702
PROCESSOR
2704
CIRCUITRY FOR DETERMINING GEOGRAPHICAL COORDINATES FOR NODES OF UNIFORM GRID
FOR EACH CALIBRATION POINT, PROGRAMMED TO:
(a) EVALUATE ASSOCIATED CALIBRATION DATA;
(b) DETERMINE IF GRID POINT SHOULD BE DEFINED BASED ON THE EVALUATION;
(c) ASSIGN GEOGRAPHICAL COORDINATES TO GRID POINT
(d) POPULATE DATABASE WITH GEOGRAPHICAL COORDINATES
(e) POPULATE DATABASE WITH INFORMATION
2703
CIRCUITRY FOR DETERMINING FOR GRID PTS.:
(a) DETERMINING CLOSEST NODE;
(b) ASSIGNING CHARACTERISTIC DATA ASSOCIATED WITH GRID PT. TO CLOSEST NODE
2705
350

FIGURE 27

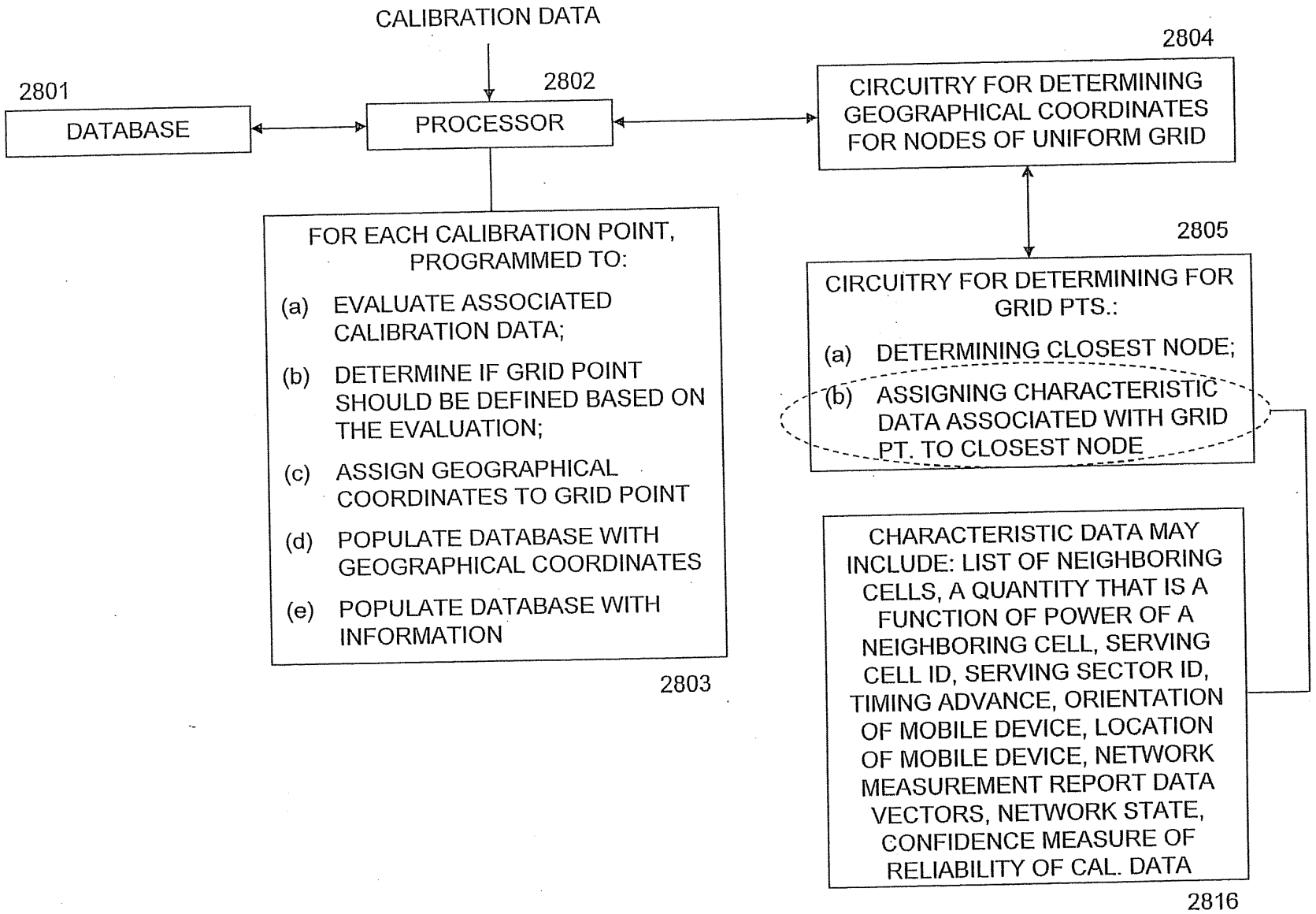

CALIBRATION DATA
2801
DATABASE
2802
PROCESSOR
2804
CIRCUITRY FOR DETERMINING GEOGRAPHICAL COORDINATES FOR NODES OF UNIFORM GRID
FOR EACH CALIBRATION POINT, PROGRAMMED TO:
(a) EVALUATE ASSOCIATED CALIBRATION DATA;
(b) DETERMINE IF GRID POINT SHOULD BE DEFINED BASED ON THE EVALUATION;
(c) ASSIGN GEOGRAPHICAL COORDINATES TO GRID POINT
(d) POPULATE DATABASE WITH GEOGRAPHICAL COORDINATES
(e) POPULATE DATABASE WITH INFORMATION
2803
2805
CIRCUITRY FOR DETERMINING FOR GRID PTS.:
(a) DETERMINING CLOSEST NODE;
(b) ASSIGNING CHARACTERISTIC DATA ASSOCIATED WITH GRID PT. TO CLOSEST NODE
CHARACTERISTIC DATA MAY INCLUDE: LIST OF NEIGHBORING CELLS, A QUANTITY THAT IS A FUNCTION OF POWER OF A NEIGHBORING CELL, SERVING CELL ID, SERVING SECTOR ID, TIMING ADVANCE, ORIENTATION OF MOBILE DEVICE, LOCATION OF MOBILE DEVICE, NETWORK MEASUREMENT REPORT DATA VECTORS, NETWORK STATE, CONFIDENCE MEASURE OF RELIABILITY OF CAL. DATA
2816

FIGURE 28

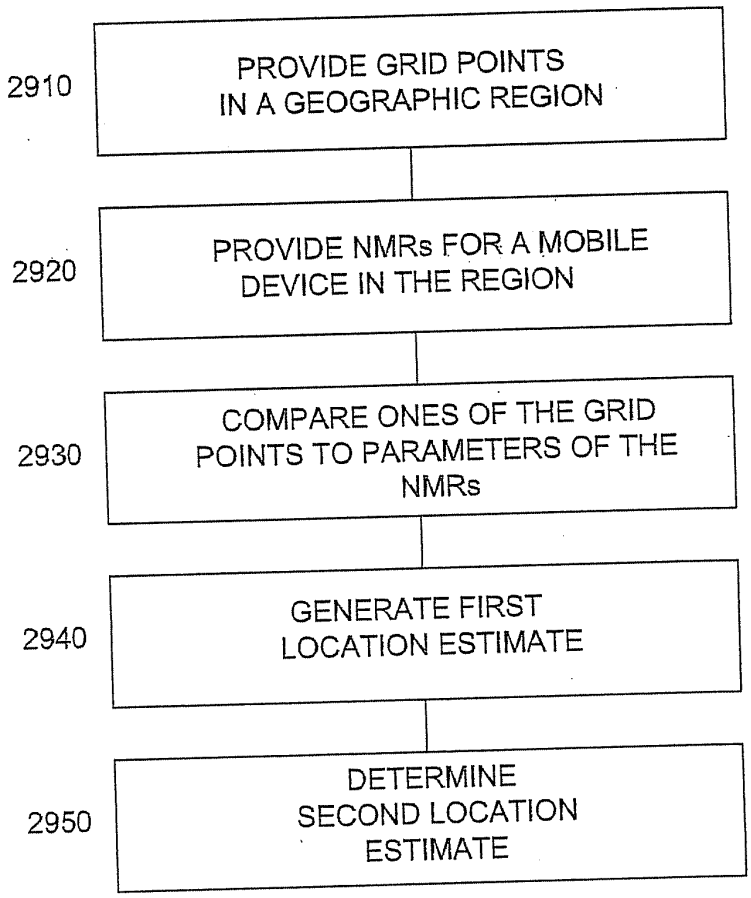

2910
PROVIDE GRID POINTS IN A GEOGRAPHIC REGION
2920
PROVIDE NMRs FOR A MOBILE DEVICE IN THE REGION
2930
COMPARE ONES OF THE GRID POINTS TO PARAMETERS OF THE NMRs
2940
GENERATE FIRST LOCATION ESTIMATE
2950
DETERMINE SECOND LOCATION ESTIMATE

FIG. 29

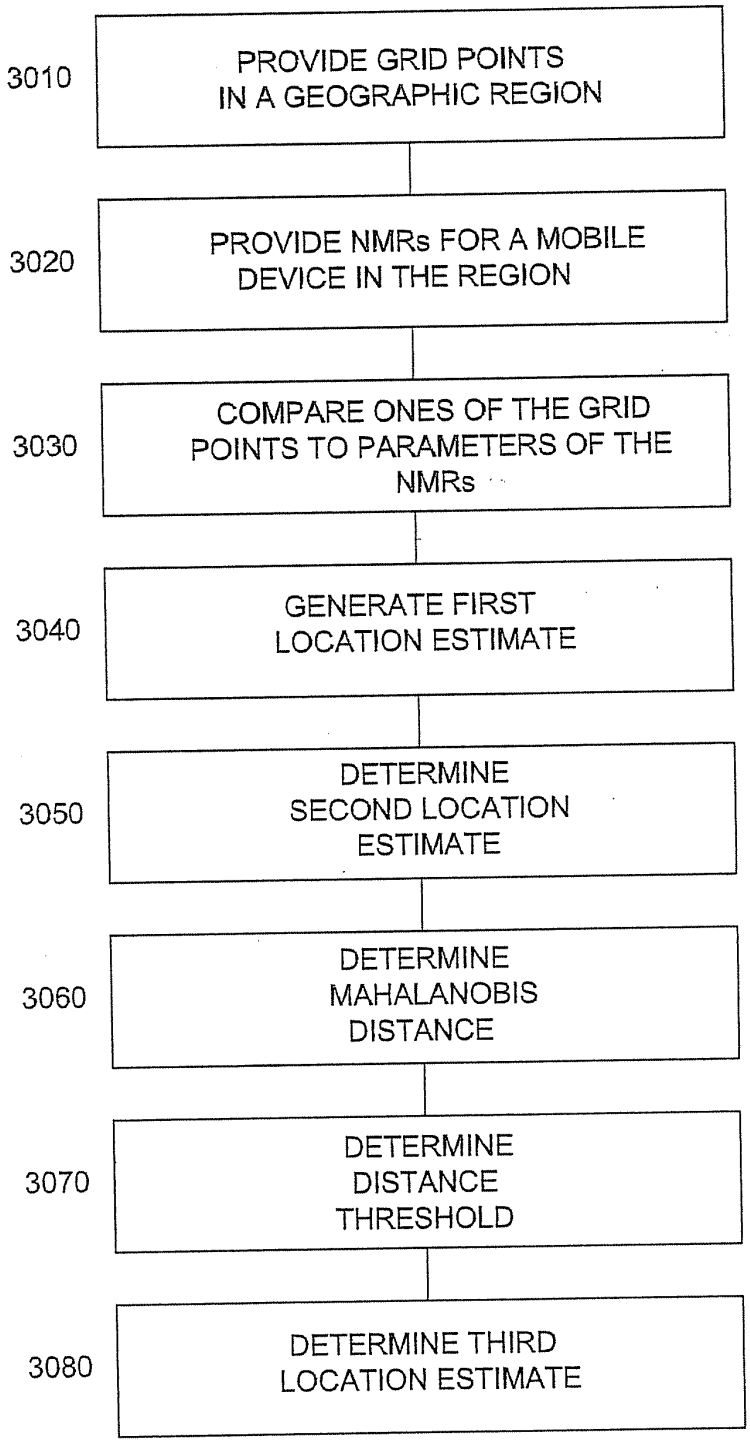

3010
PROVIDE GRID POINTS IN A GEOGRAPHIC REGION
3020
PROVIDE NMRs FOR A MOBILE DEVICE IN THE REGION
3030
COMPARE ONES OF THE GRID POINTS TO PARAMETERS OF THE NMRs
3040
GENERATE FIRST LOCATION ESTIMATE
3050
DETERMINE SECOND LOCATION ESTIMATE
3060
DETERMINE MAHALANOBIS DISTANCE
3070
DETERMINE DISTANCE THRESHOLD
3080
DETERMINE THIRD LOCATION ESTIMATE

FIG. 30

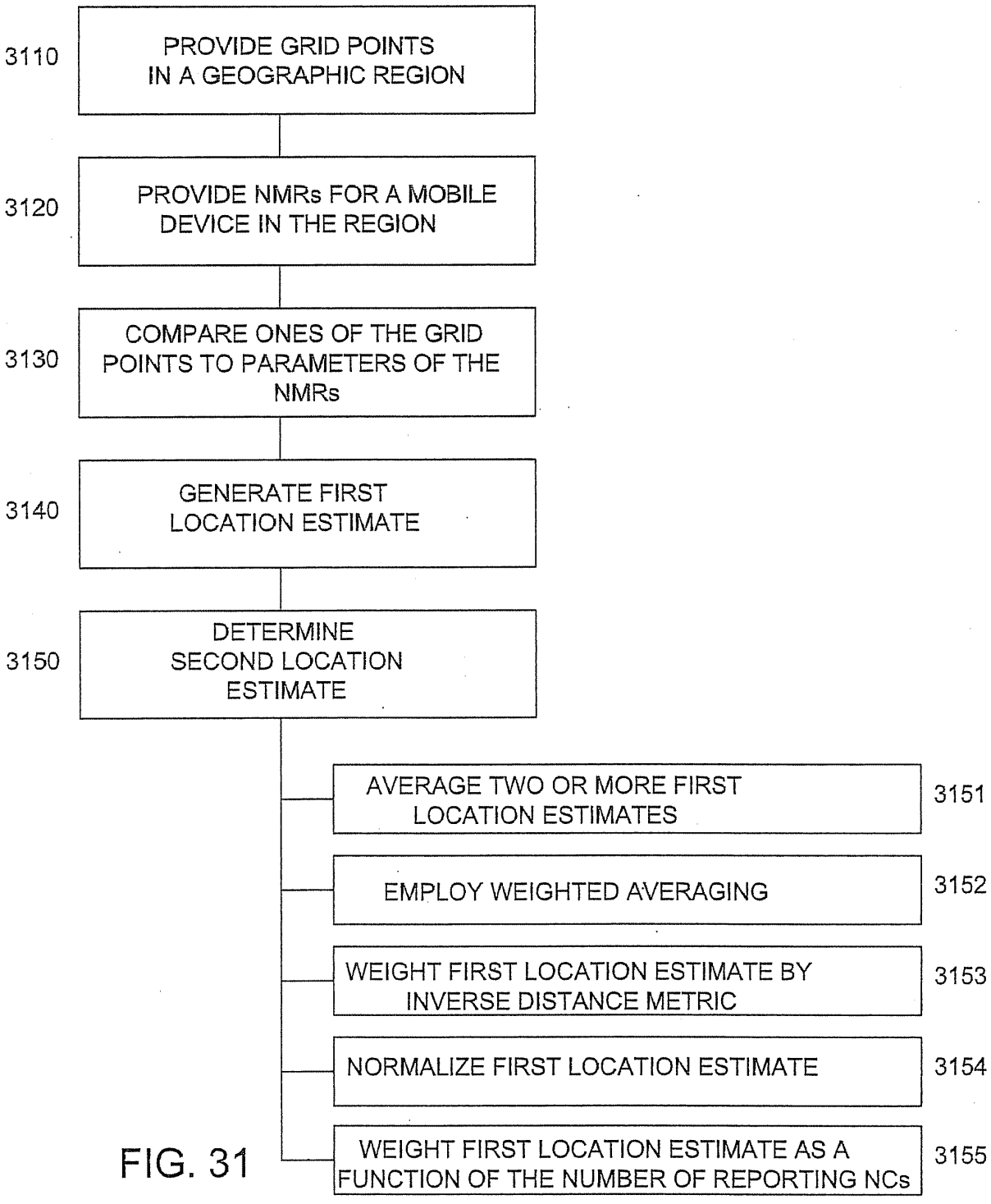

3110
PROVIDE GRID POINTS IN A GEOGRAPHIC REGION
3120
PROVIDE NMRs FOR A MOBILE DEVICE IN THE REGION
3130
COMPARE ONES OF THE GRID POINTS TO PARAMETERS OF THE NMRs
3140
GENERATE FIRST LOCATION ESTIMATE
3150
DETERMINE SECOND LOCATION ESTIMATE
AVERAGE TWO OR MORE FIRST LOCATION ESTIMATES
3151
EMPLOY WEIGHTED AVERAGING
3152
WEIGHT FIRST LOCATION ESTIMATE BY INVERSE DISTANCE METRIC
3153
NORMALIZE FIRST LOCATION ESTIMATE
3154
WEIGHT FIRST LOCATION ESTIMATE AS A FUNCTION OF THE NUMBER OF REPORTING NCs
3155

FIG. 31

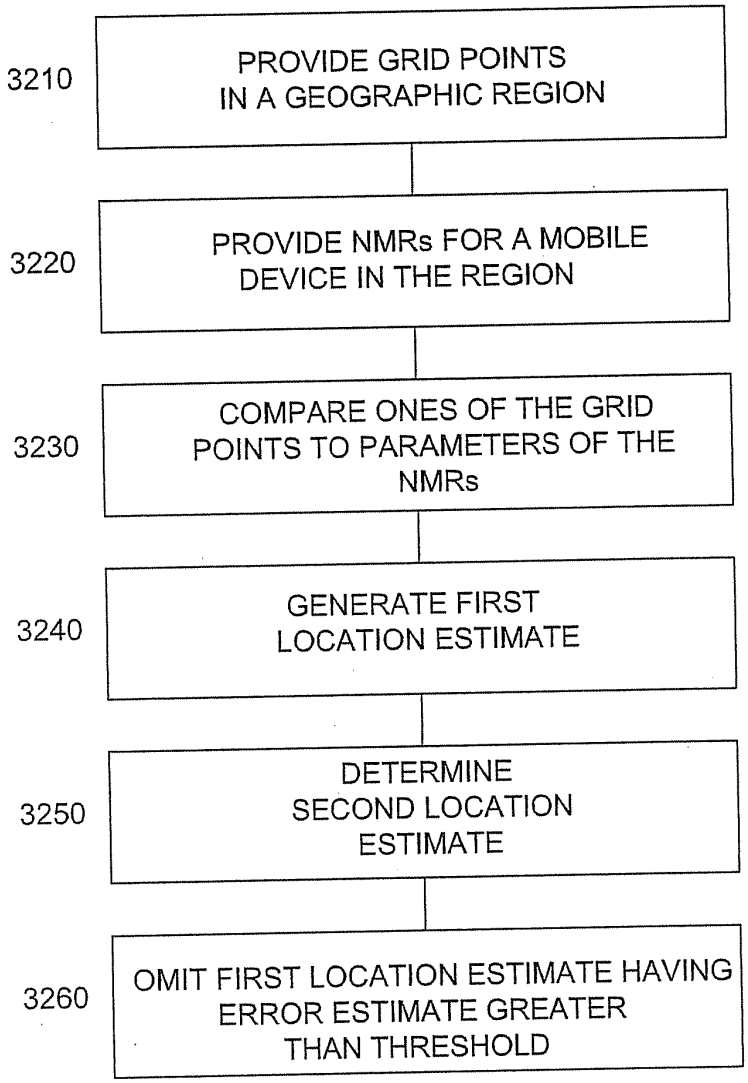

3210
PROVIDE GRID POINTS IN A GEOGRAPHIC REGION
3220
PROVIDE NMRs FOR A MOBILE DEVICE IN THE REGION
3230
COMPARE ONES OF THE GRID POINTS TO PARAMETERS OF THE NMRs
3240
GENERATE FIRST LOCATION ESTIMATE
3250
DETERMINE SECOND LOCATION ESTIMATE
3260
OMIT FIRST LOCATION ESTIMATE HAVING ERROR ESTIMATE GREATER THAN THRESHOLD

FIG. 32

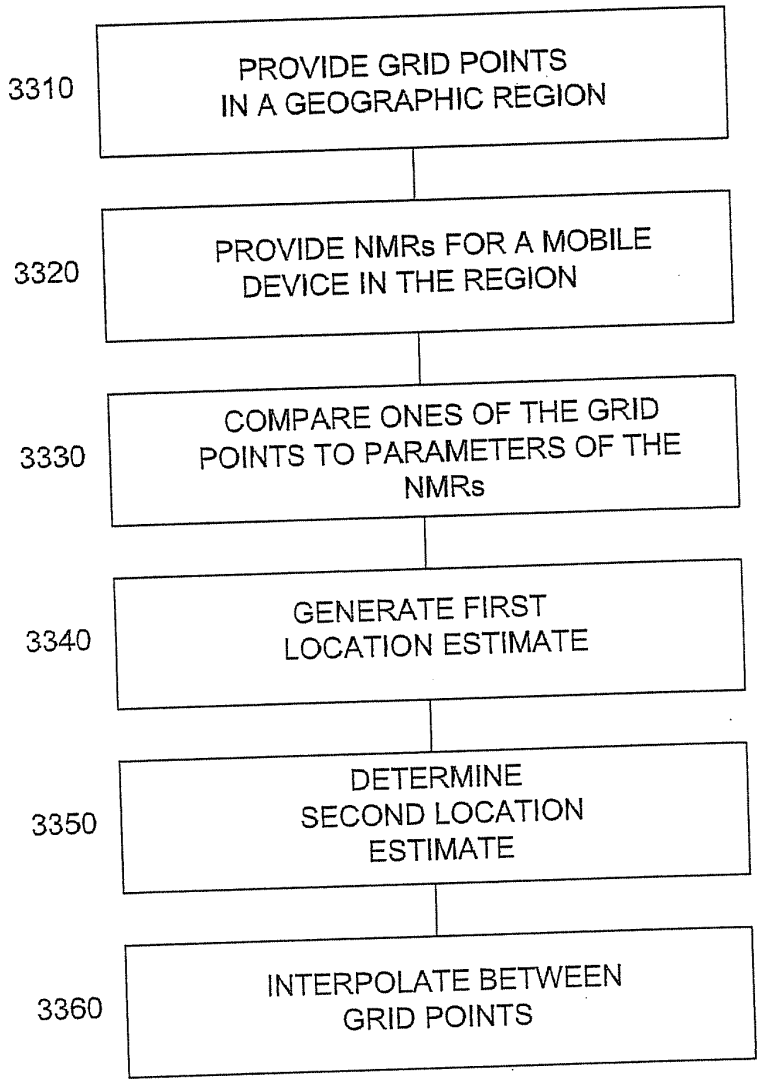

3310
PROVIDE GRID POINTS IN A GEOGRAPHIC REGION
3320
PROVIDE NMRs FOR A MOBILE DEVICE IN THE REGION
3330
COMPARE ONES OF THE GRID POINTS TO PARAMETERS OF THE NMRs
3340
GENERATE FIRST LOCATION ESTIMATE
3350
DETERMINE SECOND LOCATION ESTIMATE
3360
INTERPOLATE BETWEEN GRID POINTS

FIG. 33

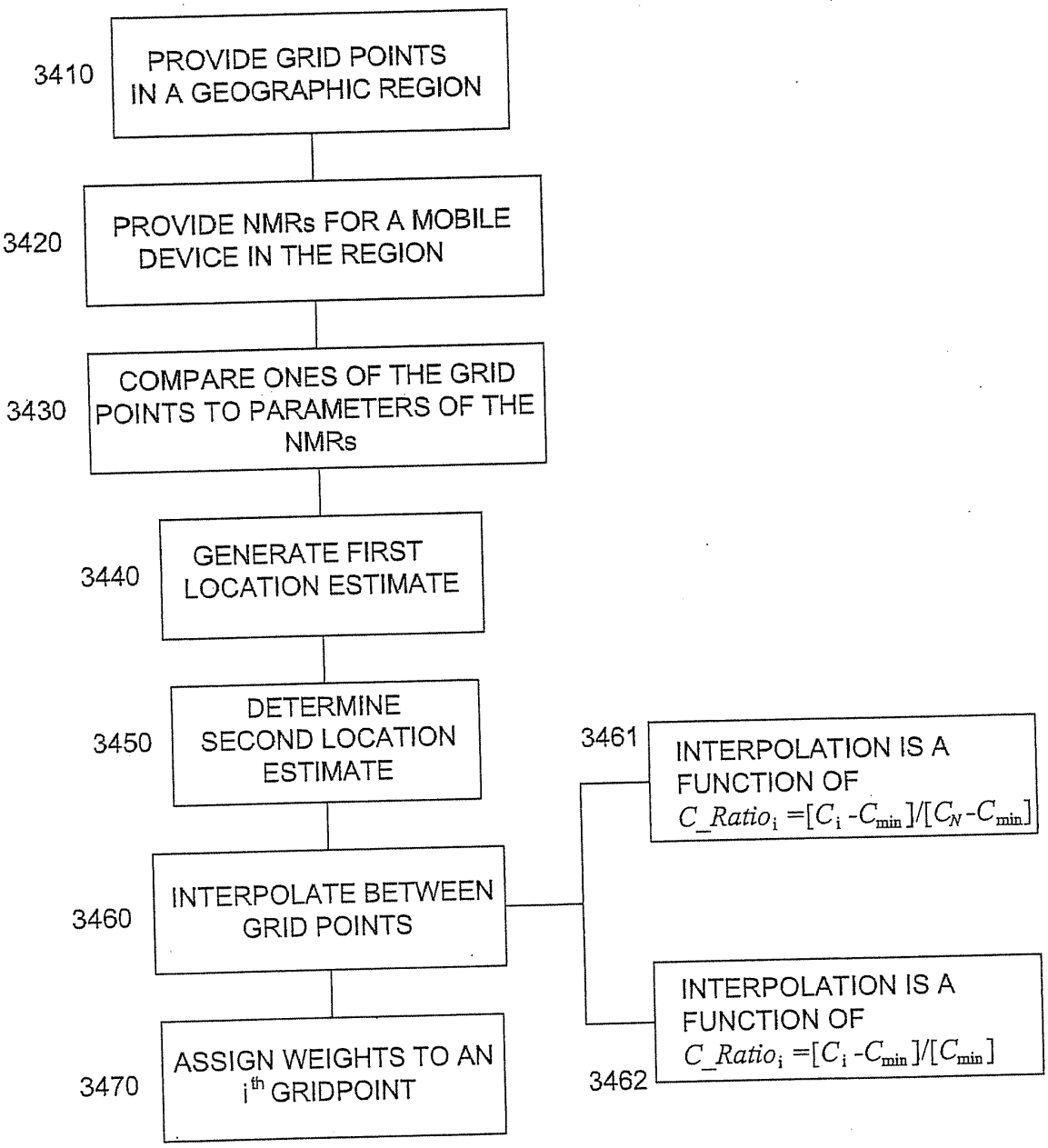

3410
PROVIDE GRID POINTS IN A GEOGRAPHIC REGION
3420
PROVIDE NMRs FOR A MOBILE DEVICE IN THE REGION
3430
COMPARE ONES OF THE GRID POINTS TO PARAMETERS OF THE NMRs
3440
GENERATE FIRST LOCATION ESTIMATE
3450
DETERMINE SECOND LOCATION ESTIMATE
3460
INTERPOLATE BETWEEN GRID POINTS
3470
ASSIGN WEIGHTS TO AN ith GRIDPOINT
3461
INTERPOLATION IS A FUNCTION OF $C\_Ratio_i = [C_i - C_{min}]/[C_N - C_{min}]$
3462
INTERPOLATION IS A FUNCTION OF $C\_Ratio_i = [C_i - C_{min}]/[C_{min}]$

FIG. 34

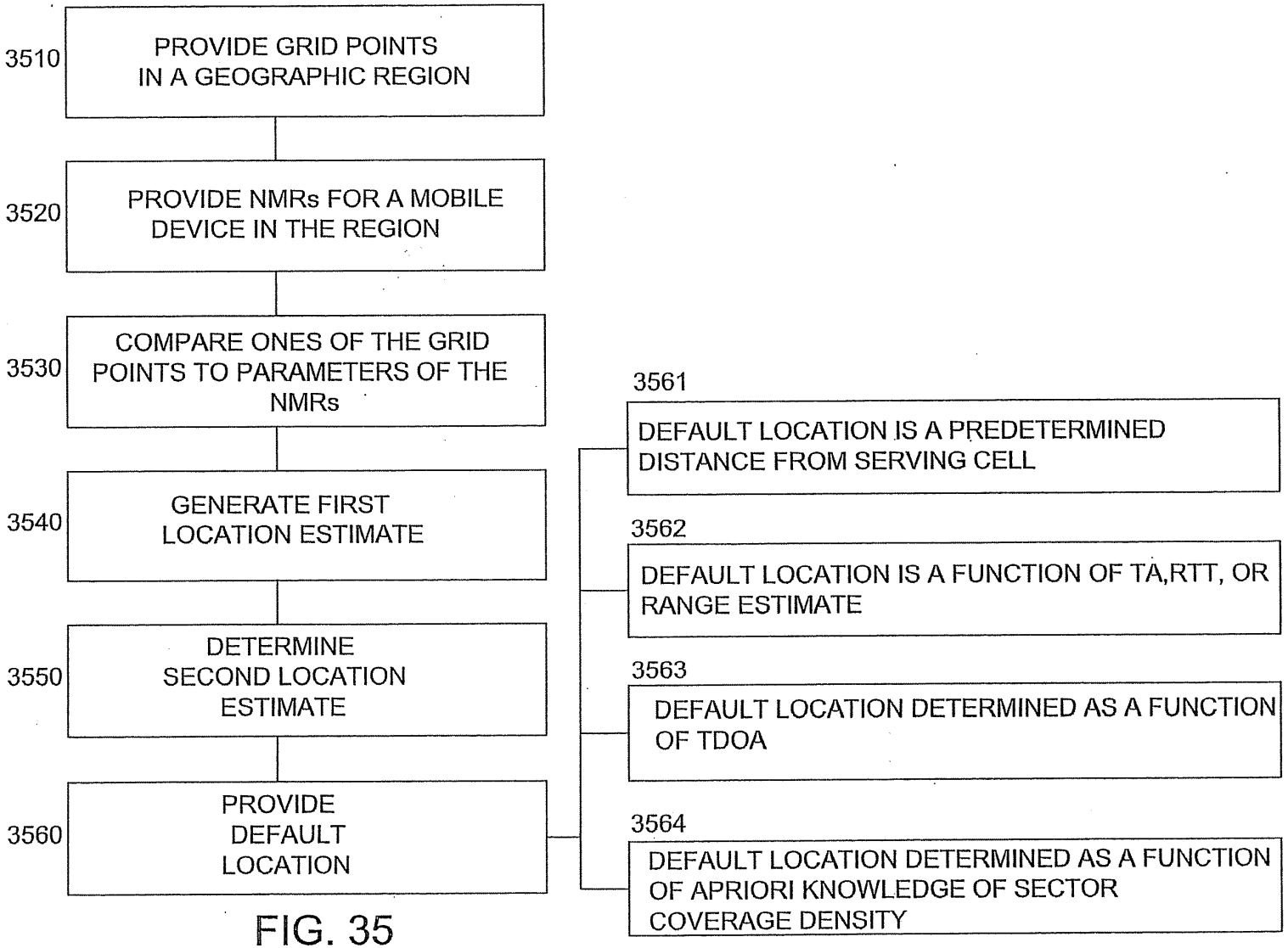

3510
PROVIDE GRID POINTS IN A GEOGRAPHIC REGION
3520
PROVIDE NMRs FOR A MOBILE DEVICE IN THE REGION
3530
COMPARE ONES OF THE GRID POINTS TO PARAMETERS OF THE NMRs
3540
GENERATE FIRST LOCATION ESTIMATE
3550
DETERMINE SECOND LOCATION ESTIMATE
3560
PROVIDE DEFAULT LOCATION
3561
DEFAULT LOCATION IS A PREDETERMINED DISTANCE FROM SERVING CELL
3562
DEFAULT LOCATION IS A FUNCTION OF TA,RTT, OR RANGE ESTIMATE
3563
DEFAULT LOCATION DETERMINED AS A FUNCTION OF TDOA
3564
DEFAULT LOCATION DETERMINED AS A FUNCTION OF APRIORI KNOWLEDGE OF SECTOR COVERAGE DENSITY

FIG. 35

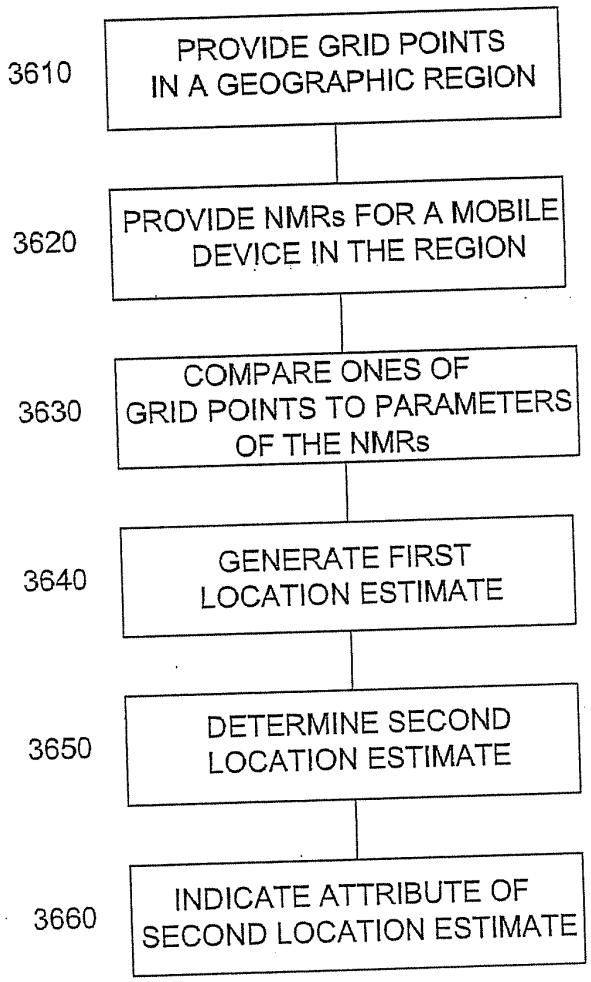

3610
PROVIDE GRID POINTS IN A GEOGRAPHIC REGION
3620
PROVIDE NMRs FOR A MOBILE DEVICE IN THE REGION
3630
COMPARE ONES OF GRID POINTS TO PARAMETERS OF THE NMRs
3640
GENERATE FIRST LOCATION ESTIMATE
3650
DETERMINE SECOND LOCATION ESTIMATE
3660
INDICATE ATTRIBUTE OF SECOND LOCATION ESTIMATE

FIG. 36

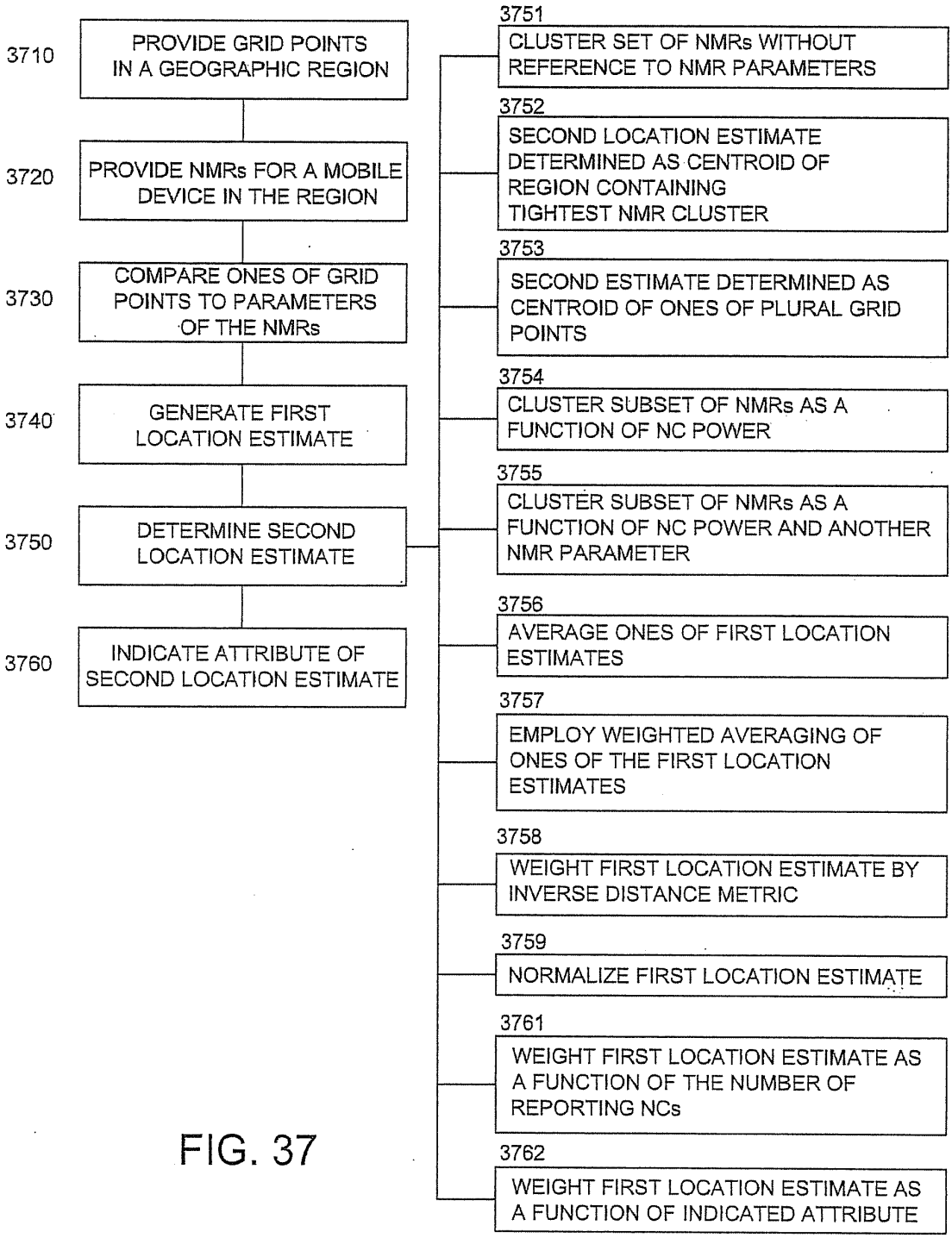

3710
PROVIDE GRID POINTS IN A GEOGRAPHIC REGION
3720
PROVIDE NMRs FOR A MOBILE DEVICE IN THE REGION
3730
COMPARE ONES OF GRID POINTS TO PARAMETERS OF THE NMRs
3740
GENERATE FIRST LOCATION ESTIMATE
3750
DETERMINE SECOND LOCATION ESTIMATE
3760
INDICATE ATTRIBUTE OF SECOND LOCATION ESTIMATE
3751
CLUSTER SET OF NMRs WITHOUT REFERENCE TO NMR PARAMETERS
3752
SECOND LOCATION ESTIMATE DETERMINED AS CENTROID OF REGION CONTAINING TIGHTEST NMR CLUSTER
3753
SECOND ESTIMATE DETERMINED AS CENTROID OF ONES OF PLURAL GRID POINTS
3754
CLUSTER SUBSET OF NMRs AS A FUNCTION OF NC POWER
3755
CLUSTER SUBSET OF NMRs AS A FUNCTION OF NC POWER AND ANOTHER NMR PARAMETER
3756
AVERAGE ONES OF FIRST LOCATION ESTIMATES
3757
EMPLOY WEIGHTED AVERAGING OF ONES OF THE FIRST LOCATION ESTIMATES
3758
WEIGHT FIRST LOCATION ESTIMATE BY INVERSE DISTANCE METRIC
3759
NORMALIZE FIRST LOCATION ESTIMATE
3761
WEIGHT FIRST LOCATION ESTIMATE AS A FUNCTION OF THE NUMBER OF REPORTING NCs
3762
WEIGHT FIRST LOCATION ESTIMATE AS A FUNCTION OF INDICATED ATTRIBUTE

FIG. 37

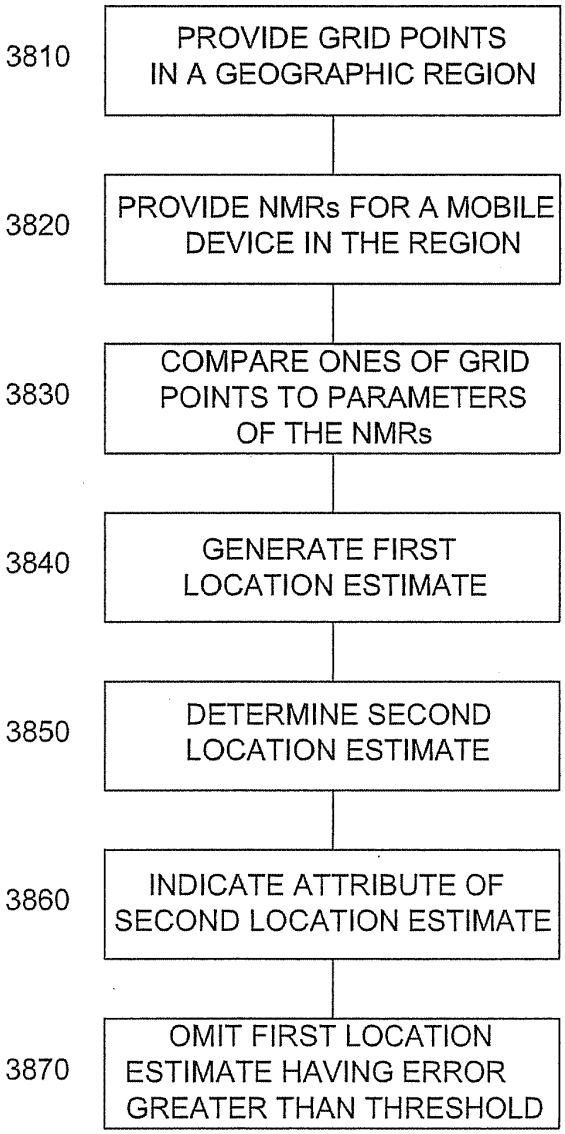

3810
PROVIDE GRID POINTS IN A GEOGRAPHIC REGION
3820
PROVIDE NMRs FOR A MOBILE DEVICE IN THE REGION
3830
COMPARE ONES OF GRID POINTS TO PARAMETERS OF THE NMRs
3840
GENERATE FIRST LOCATION ESTIMATE
3850
DETERMINE SECOND LOCATION ESTIMATE
3860
INDICATE ATTRIBUTE OF SECOND LOCATION ESTIMATE
3870
OMIT FIRST LOCATION ESTIMATE HAVING ERROR GREATER THAN THRESHOLD

FIG. 38

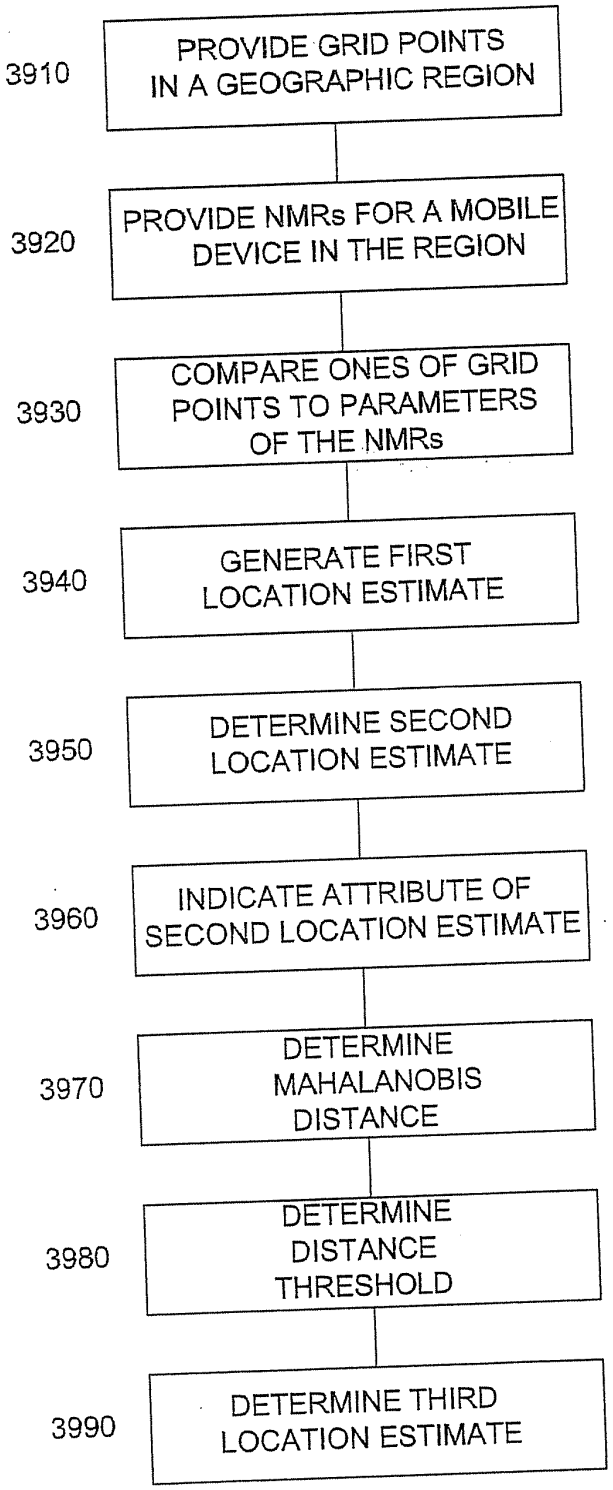

3910
PROVIDE GRID POINTS IN A GEOGRAPHIC REGION
3920
PROVIDE NMRs FOR A MOBILE DEVICE IN THE REGION
3930
COMPARE ONES OF GRID POINTS TO PARAMETERS OF THE NMRs
3940
GENERATE FIRST LOCATION ESTIMATE
3950
DETERMINE SECOND LOCATION ESTIMATE
3960
INDICATE ATTRIBUTE OF SECOND LOCATION ESTIMATE
3970
DETERMINE MAHALANOBIS DISTANCE
3980
DETERMINE DISTANCE THRESHOLD
3990
DETERMINE THIRD LOCATION ESTIMATE

FIG. 39

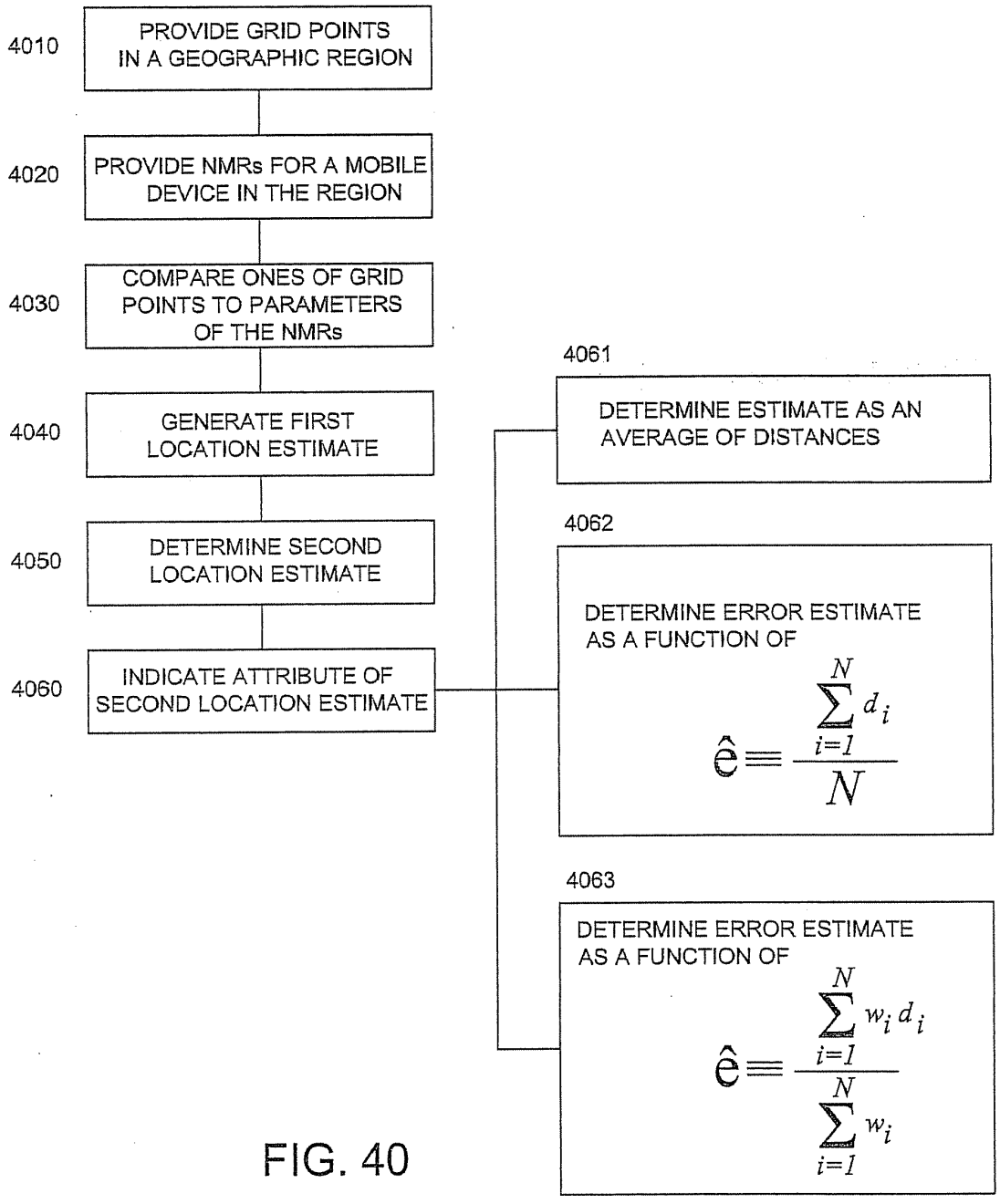

4010
PROVIDE GRID POINTS IN A GEOGRAPHIC REGION
4020
PROVIDE NMRs FOR A MOBILE DEVICE IN THE REGION
4030
COMPARE ONES OF GRID POINTS TO PARAMETERS OF THE NMRs
4040
GENERATE FIRST LOCATION ESTIMATE
4050
DETERMINE SECOND LOCATION ESTIMATE
4060
INDICATE ATTRIBUTE OF SECOND LOCATION ESTIMATE
4061
DETERMINE ESTIMATE AS AN AVERAGE OF DISTANCES
4062
DETERMINE ERROR ESTIMATE AS A FUNCTION OF
$\hat{e} \equiv \frac{\sum_{i=1}^{N} d_i}{N}$
4063
DETERMINE ERROR ESTIMATE AS A FUNCTION OF
$\hat{e} \equiv \frac{\sum_{i=1}^{N} w_i d_i}{\sum_{i=1}^{N} w_i}$

FIG. 40

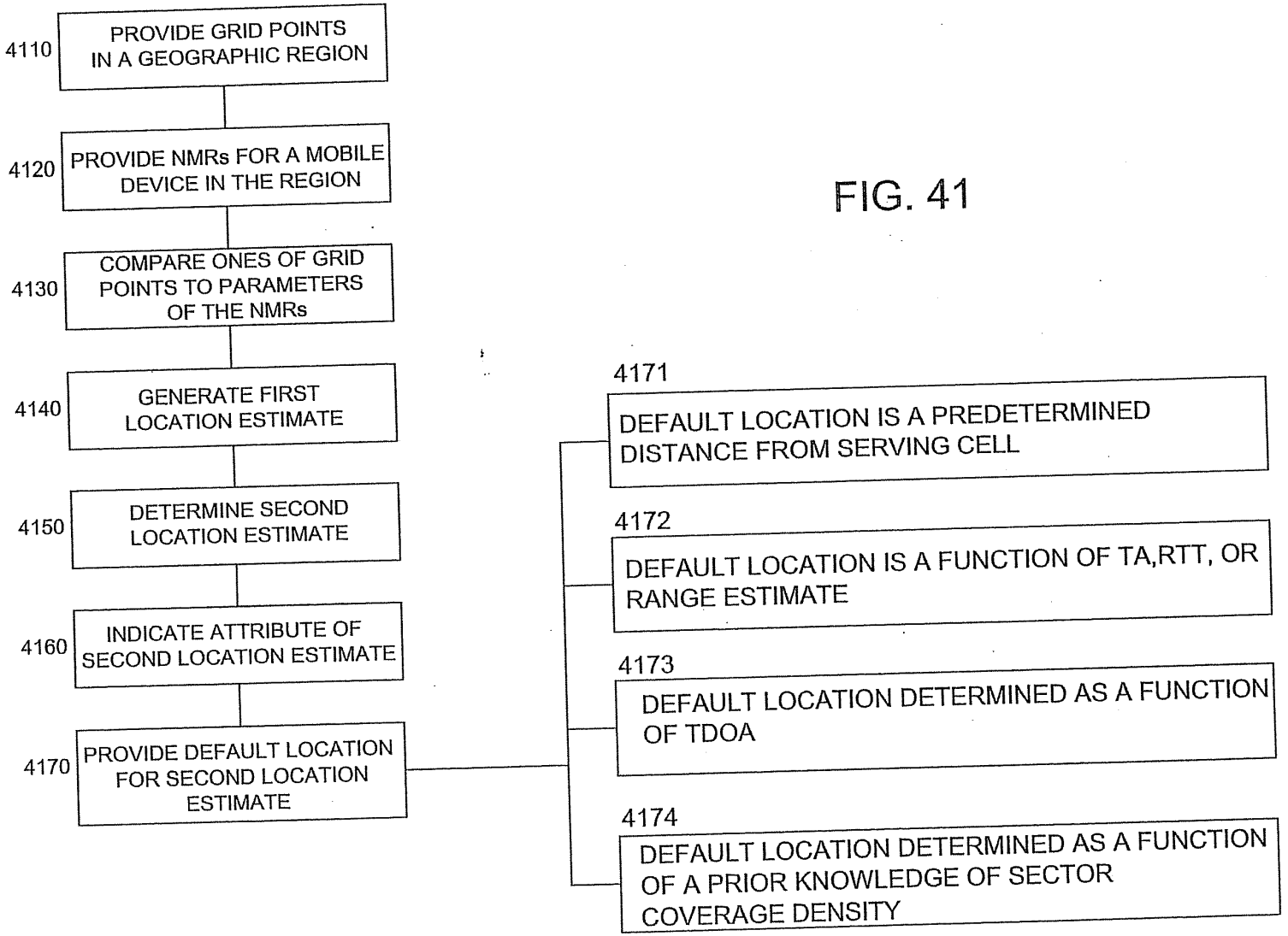

4110
PROVIDE GRID POINTS IN A GEOGRAPHIC REGION
4120
PROVIDE NMRs FOR A MOBILE DEVICE IN THE REGION
4130
COMPARE ONES OF GRID POINTS TO PARAMETERS OF THE NMRs
4140
GENERATE FIRST LOCATION ESTIMATE
4150
DETERMINE SECOND LOCATION ESTIMATE
4160
INDICATE ATTRIBUTE OF SECOND LOCATION ESTIMATE
4170
PROVIDE DEFAULT LOCATION FOR SECOND LOCATION ESTIMATE
4171
DEFAULT LOCATION IS A PREDETERMINED DISTANCE FROM SERVING CELL
4172
DEFAULT LOCATION IS A FUNCTION OF TA,RTT, OR RANGE ESTIMATE
4173
DEFAULT LOCATION DETERMINED AS A FUNCTION OF TDOA
4174
DEFAULT LOCATION DETERMINED AS A FUNCTION OF A PRIOR KNOWLEDGE OF SECTOR COVERAGE DENSITY

FIG. 41

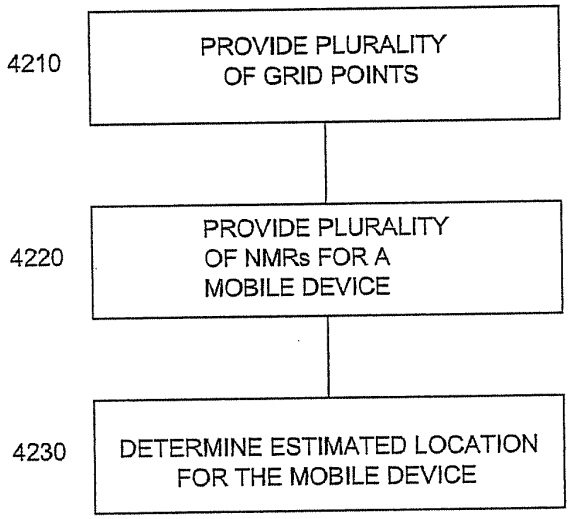

4210
PROVIDE PLURALITY OF GRID POINTS
4220
PROVIDE PLURALITY OF NMRs FOR A MOBILE DEVICE
4230
DETERMINE ESTIMATED LOCATION FOR THE MOBILE DEVICE

FIG. 42

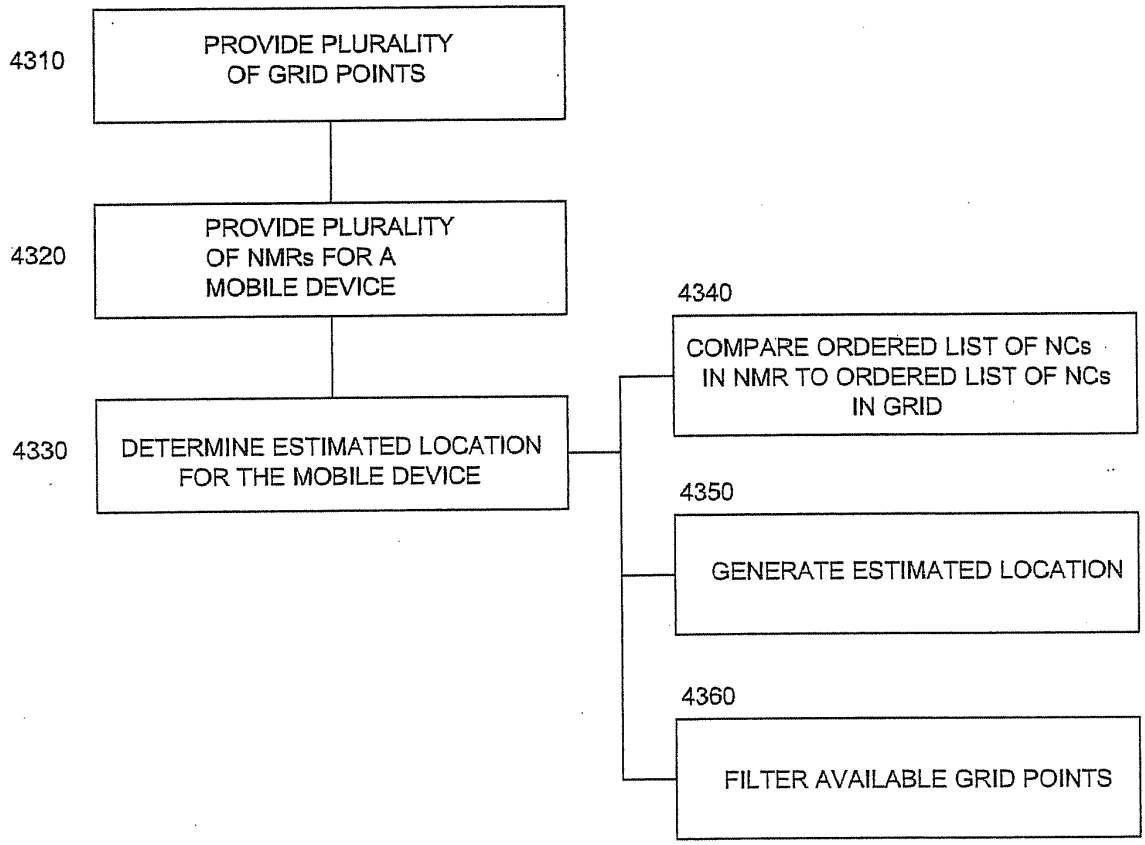

4310
PROVIDE PLURALITY OF GRID POINTS
4320
PROVIDE PLURALITY OF NMRs FOR A MOBILE DEVICE
4330
DETERMINE ESTIMATED LOCATION FOR THE MOBILE DEVICE
4340
COMPARE ORDERED LIST OF NCs IN NMR TO ORDERED LIST OF NCs IN GRID
4350
GENERATE ESTIMATED LOCATION
4360
FILTER AVAILABLE GRID POINTS

FIG. 43

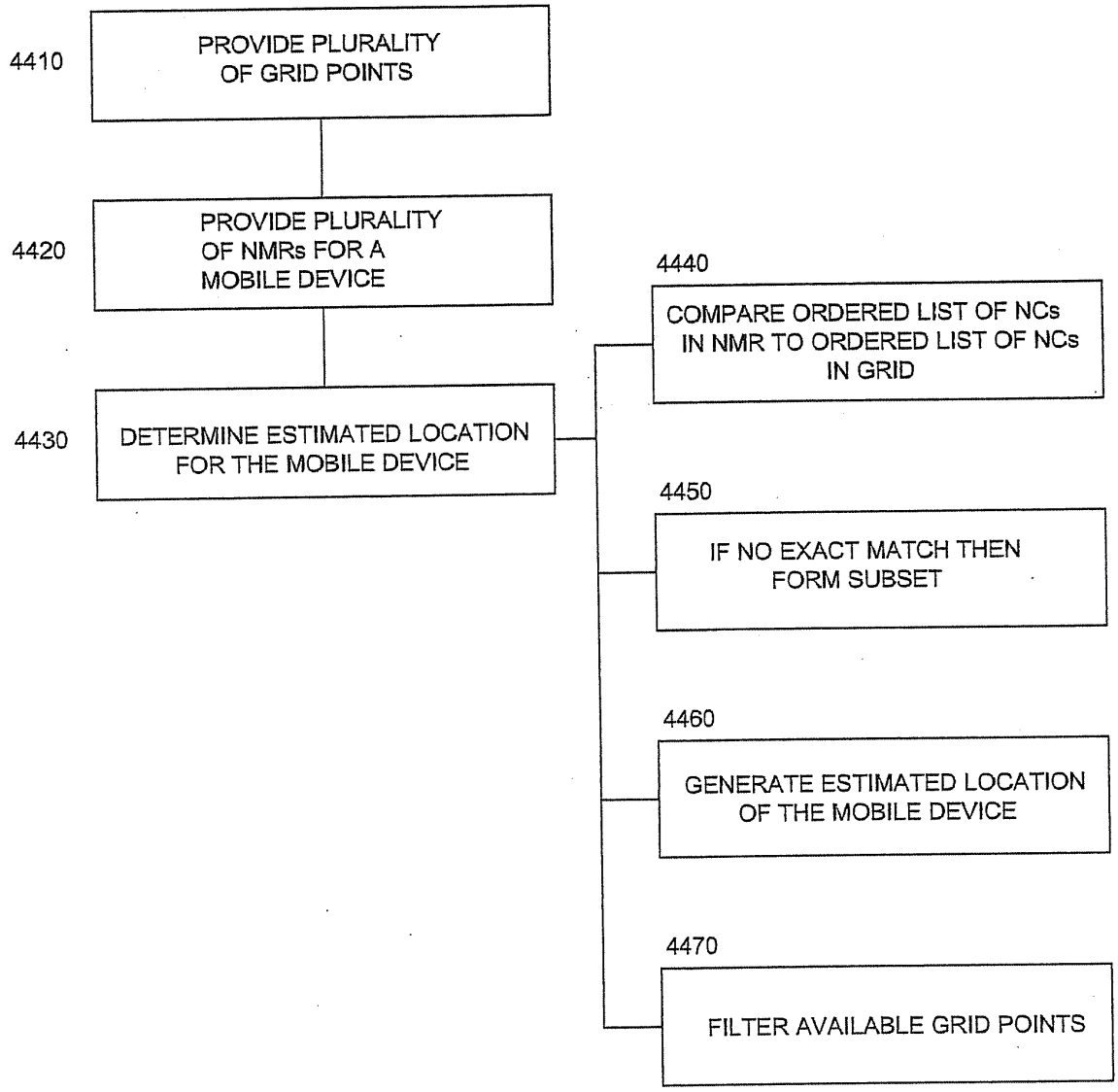

4410
PROVIDE PLURALITY OF GRID POINTS
4420
PROVIDE PLURALITY OF NMRs FOR A MOBILE DEVICE
4430
DETERMINE ESTIMATED LOCATION FOR THE MOBILE DEVICE
4440
COMPARE ORDERED LIST OF NCs IN NMR TO ORDERED LIST OF NCs IN GRID
4450
IF NO EXACT MATCH THEN FORM SUBSET
4460
GENERATE ESTIMATED LOCATION OF THE MOBILE DEVICE
4470
FILTER AVAILABLE GRID POINTS

FIG. 44

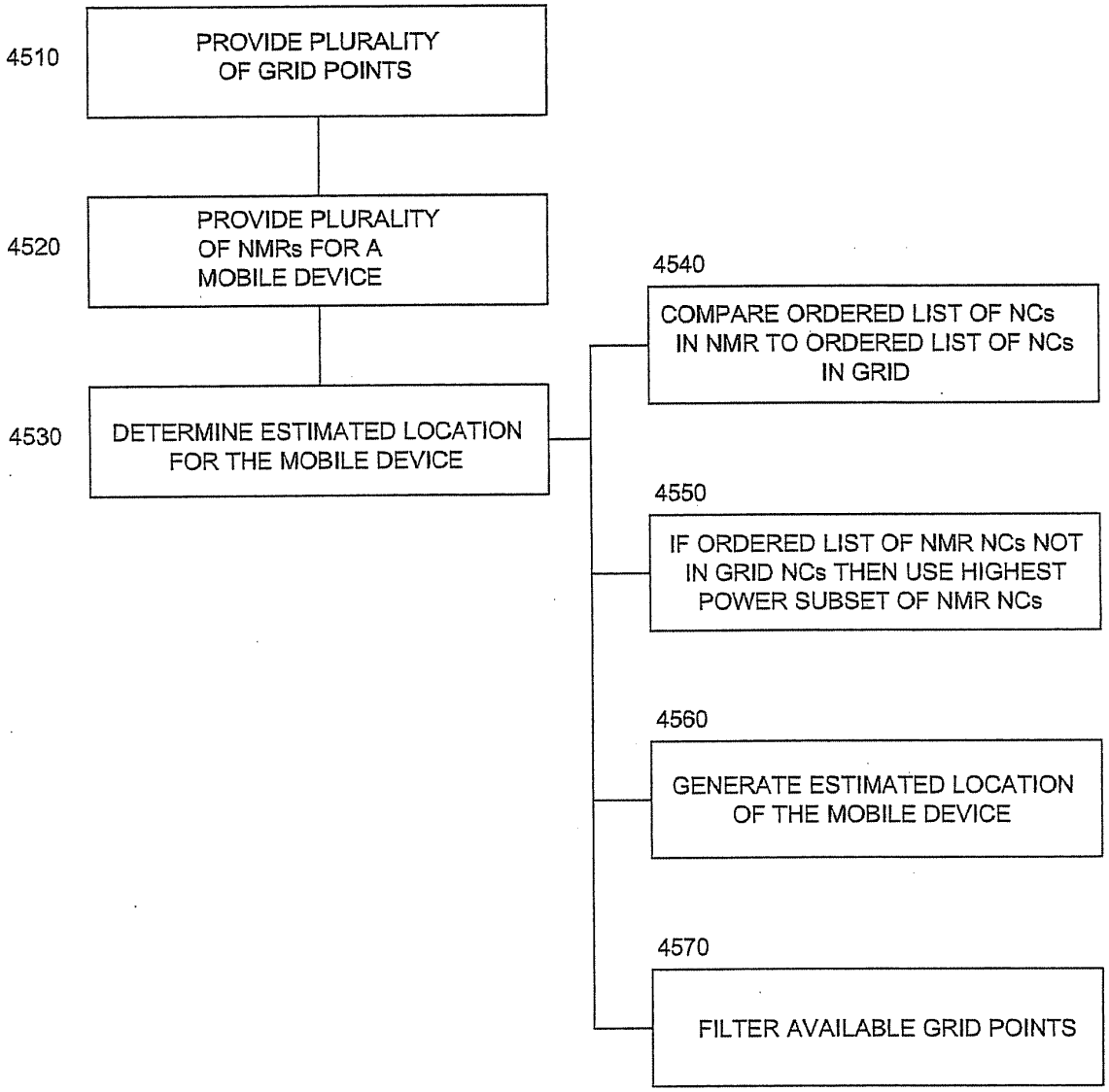

4510
PROVIDE PLURALITY OF GRID POINTS
4520
PROVIDE PLURALITY OF NMRs FOR A MOBILE DEVICE
4530
DETERMINE ESTIMATED LOCATION FOR THE MOBILE DEVICE
4540
COMPARE ORDERED LIST OF NCs IN NMR TO ORDERED LIST OF NCs IN GRID
4550
IF ORDERED LIST OF NMR NCs NOT IN GRID NCs THEN USE HIGHEST POWER SUBSET OF NMR NCs
4560
GENERATE ESTIMATED LOCATION OF THE MOBILE DEVICE
4570
FILTER AVAILABLE GRID POINTS

FIG. 45

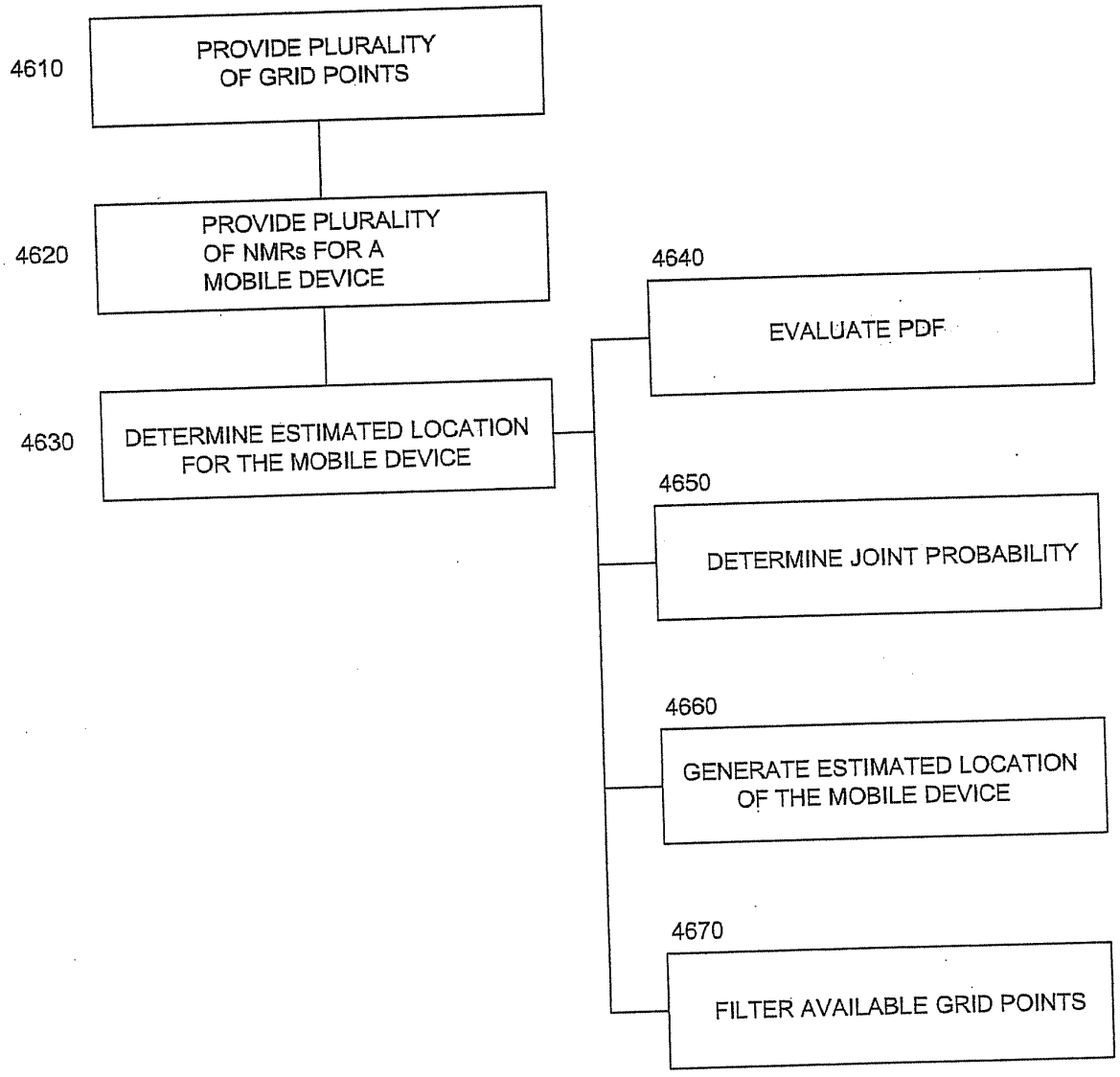

4610
PROVIDE PLURALITY OF GRID POINTS
4620
PROVIDE PLURALITY OF NMRs FOR A MOBILE DEVICE
4630
DETERMINE ESTIMATED LOCATION FOR THE MOBILE DEVICE
4640
EVALUATE PDF
4650
DETERMINE JOINT PROBABILITY
4660
GENERATE ESTIMATED LOCATION OF THE MOBILE DEVICE
4670
FILTER AVAILABLE GRID POINTS

FIG. 46

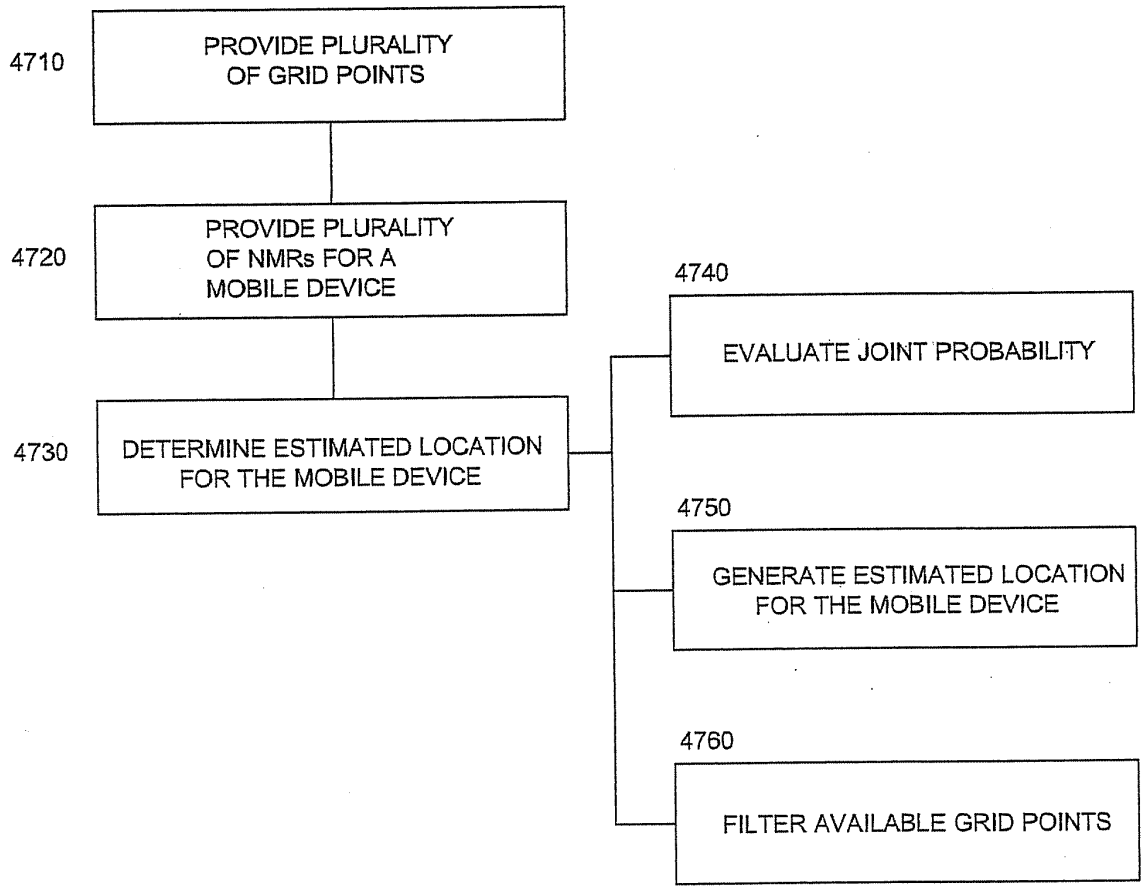

4710
PROVIDE PLURALITY OF GRID POINTS
4720
PROVIDE PLURALITY OF NMRs FOR A MOBILE DEVICE
4730
DETERMINE ESTIMATED LOCATION FOR THE MOBILE DEVICE
4740
EVALUATE JOINT PROBABILITY
4750
GENERATE ESTIMATED LOCATION FOR THE MOBILE DEVICE
4760
FILTER AVAILABLE GRID POINTS

FIG. 47

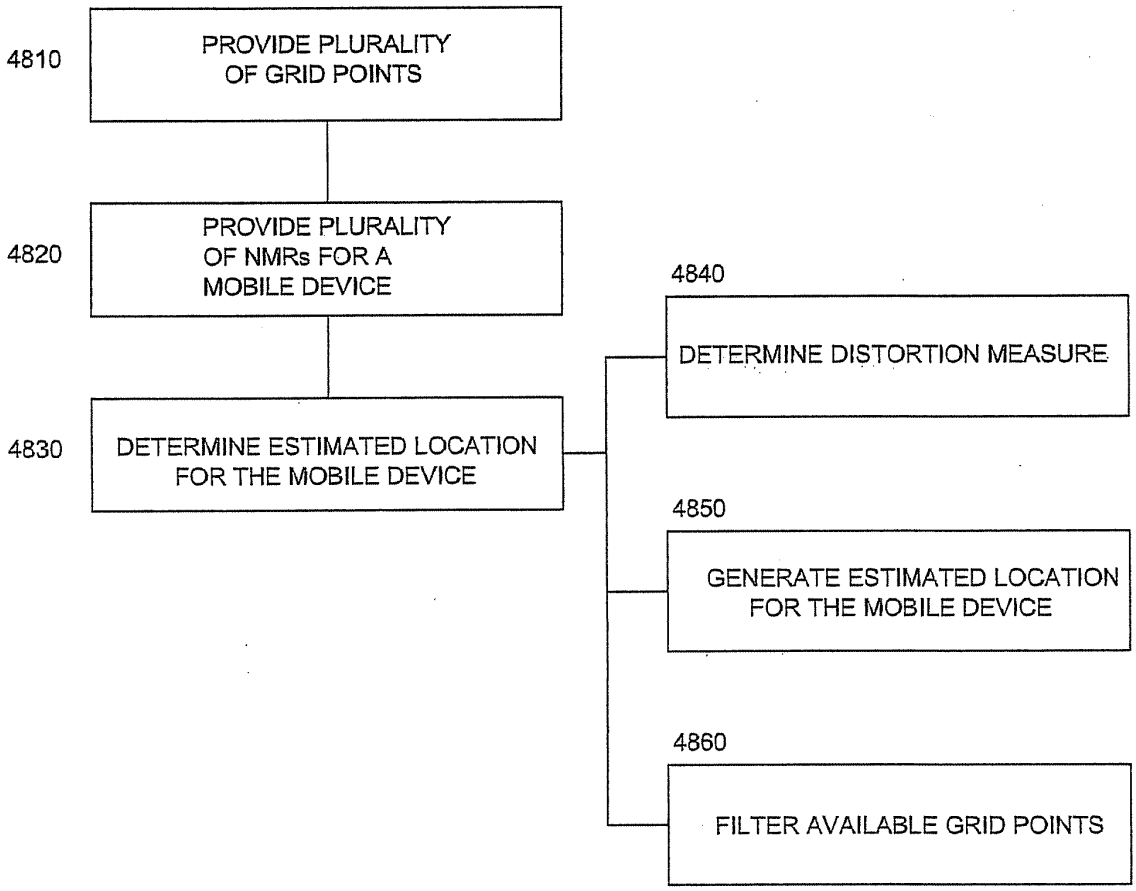

4810
PROVIDE PLURALITY OF GRID POINTS
4820
PROVIDE PLURALITY OF NMRs FOR A MOBILE DEVICE
4830
DETERMINE ESTIMATED LOCATION FOR THE MOBILE DEVICE
4840
DETERMINE DISTORTION MEASURE
4850
GENERATE ESTIMATED LOCATION FOR THE MOBILE DEVICE
4860
FILTER AVAILABLE GRID POINTS

FIG. 48

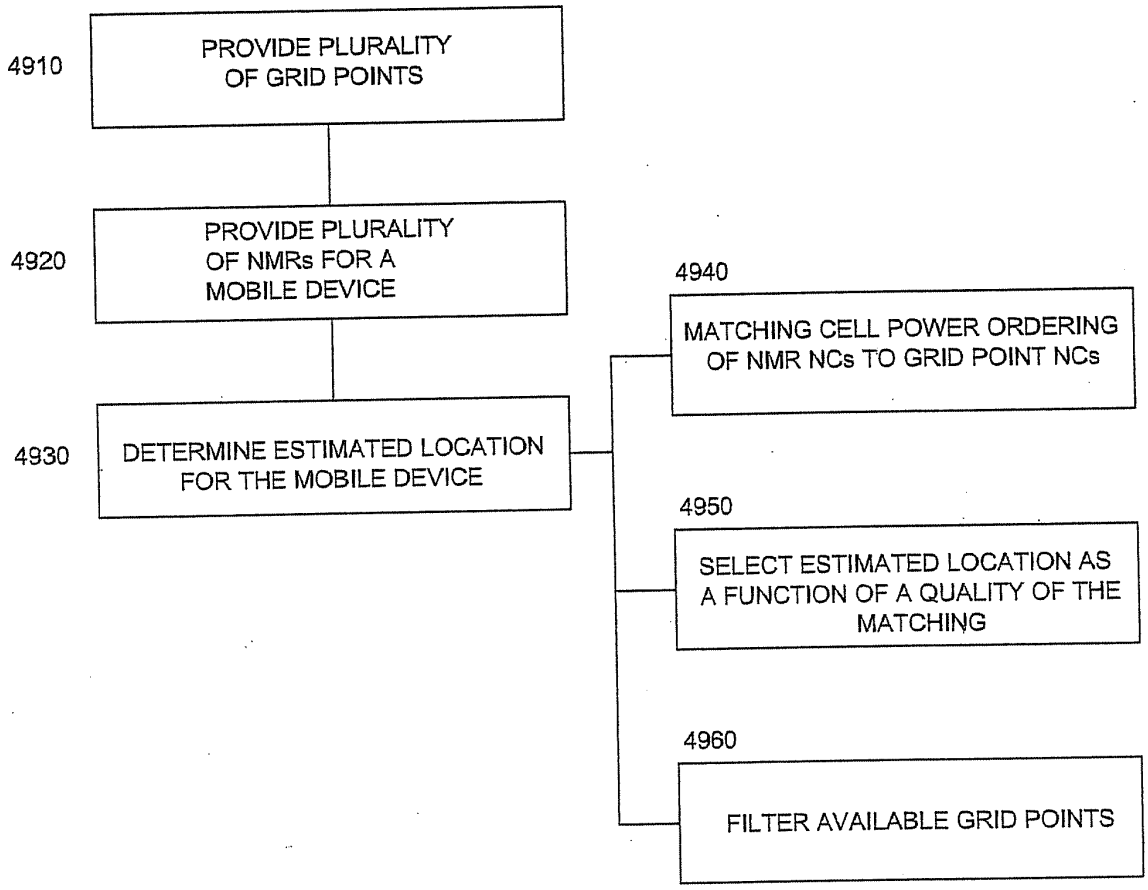

4910
PROVIDE PLURALITY OF GRID POINTS
4920
PROVIDE PLURALITY OF NMRs FOR A MOBILE DEVICE
4930
DETERMINE ESTIMATED LOCATION FOR THE MOBILE DEVICE
4940
MATCHING CELL POWER ORDERING OF NMR NCs TO GRID POINT NCs
4950
SELECT ESTIMATED LOCATION AS A FUNCTION OF A QUALITY OF THE MATCHING
4960
FILTER AVAILABLE GRID POINTS

FIG. 49

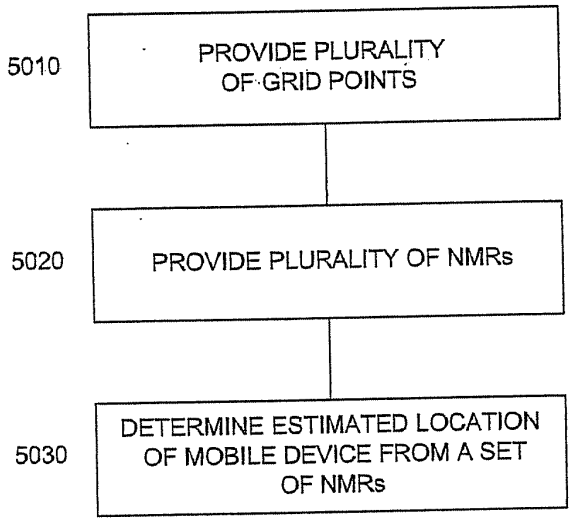

5010
PROVIDE PLURALITY OF GRID POINTS
5020
PROVIDE PLURALITY OF NMRs
5030
DETERMINE ESTIMATED LOCATION OF MOBILE DEVICE FROM A SET OF NMRs

FIG. 50

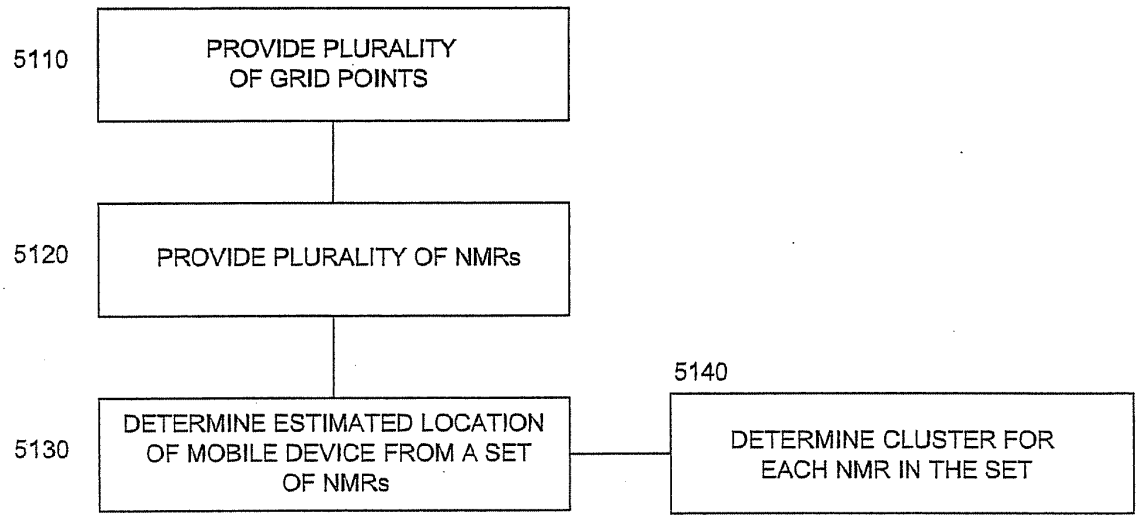

5110
PROVIDE PLURALITY OF GRID POINTS
5120
PROVIDE PLURALITY OF NMRs
5130
DETERMINE ESTIMATED LOCATION OF MOBILE DEVICE FROM A SET OF NMRs
5140
DETERMINE CLUSTER FOR EACH NMR IN THE SET

FIG. 51

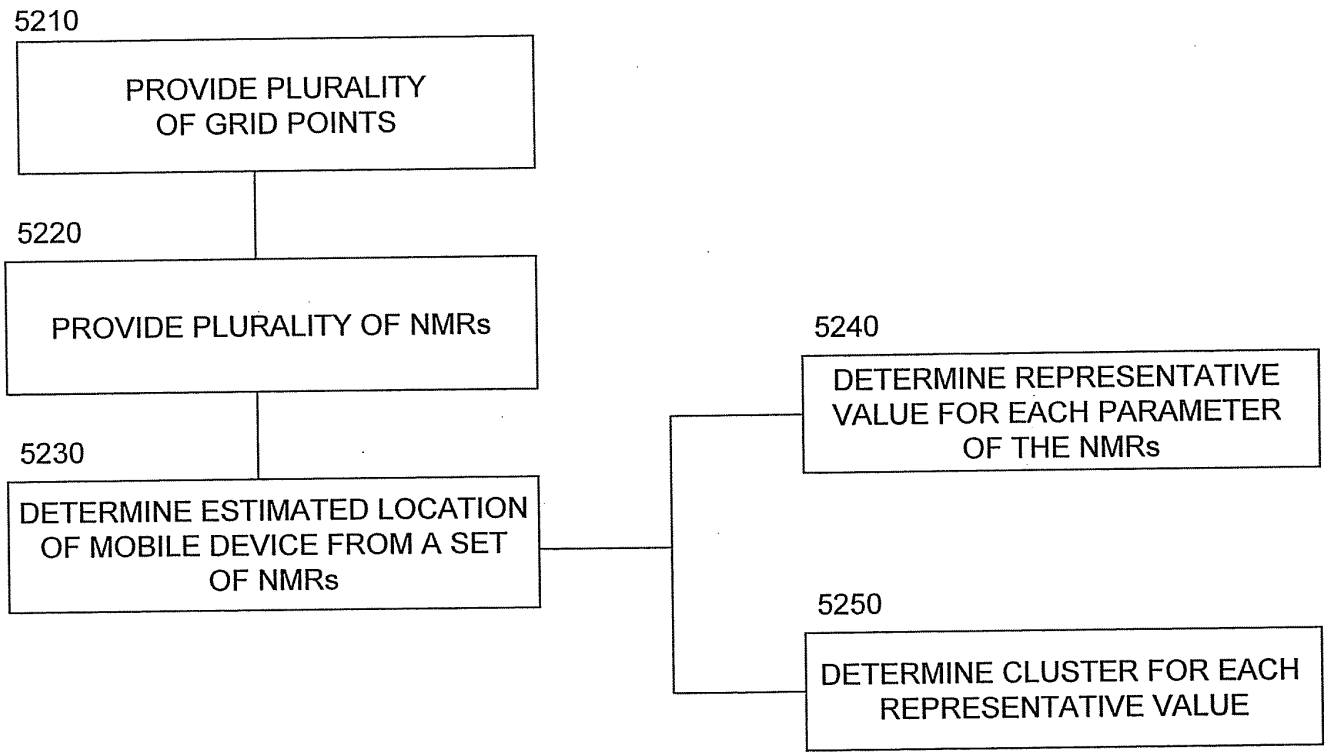

5210
PROVIDE PLURALITY OF GRID POINTS
5220
PROVIDE PLURALITY OF NMRs
5230
DETERMINE ESTIMATED LOCATION OF MOBILE DEVICE FROM A SET OF NMRs
5240
DETERMINE REPRESENTATIVE VALUE FOR EACH PARAMETER OF THE NMRs
5250
DETERMINE CLUSTER FOR EACH REPRESENTATIVE VALUE

FIGURE 52

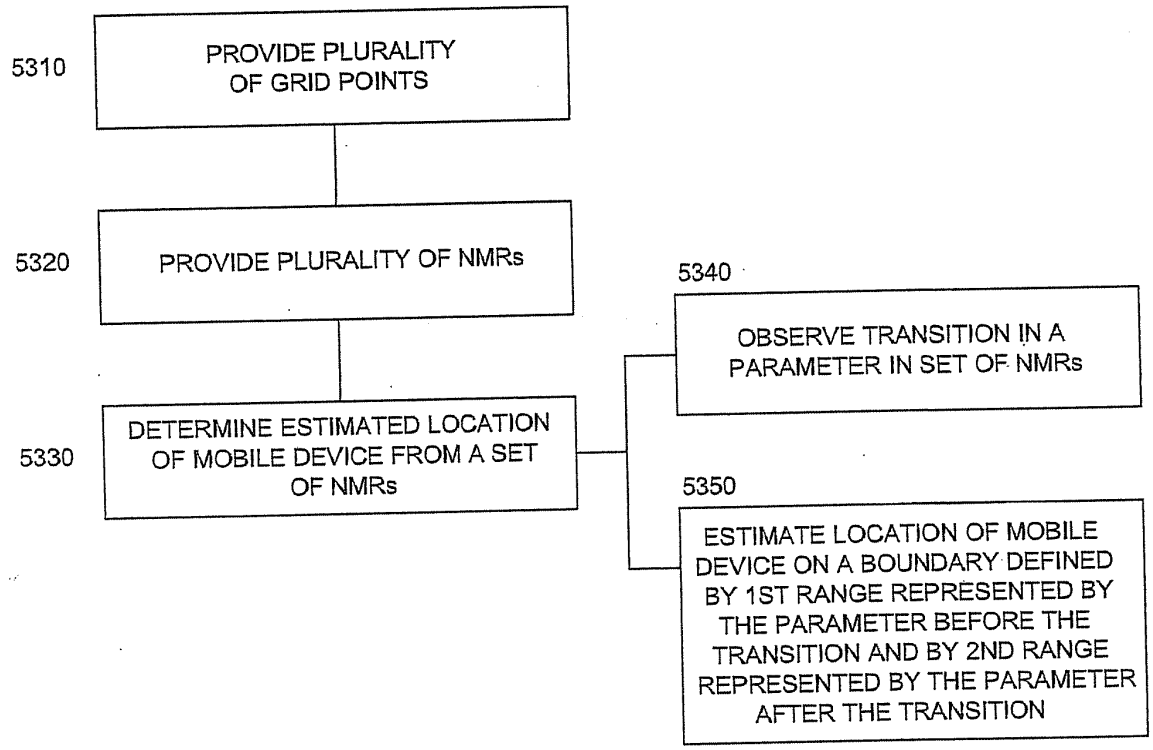

5310
PROVIDE PLURALITY OF GRID POINTS
5320
PROVIDE PLURALITY OF NMRs
5330
DETERMINE ESTIMATED LOCATION OF MOBILE DEVICE FROM A SET OF NMRs
5340
OBSERVE TRANSITION IN A PARAMETER IN SET OF NMRs
5350
ESTIMATE LOCATION OF MOBILE DEVICE ON A BOUNDARY DEFINED BY 1ST RANGE REPRESENTED BY THE PARAMETER BEFORE THE TRANSITION AND BY 2ND RANGE REPRESENTED BY THE PARAMETER AFTER THE TRANSITION

FIG. 53

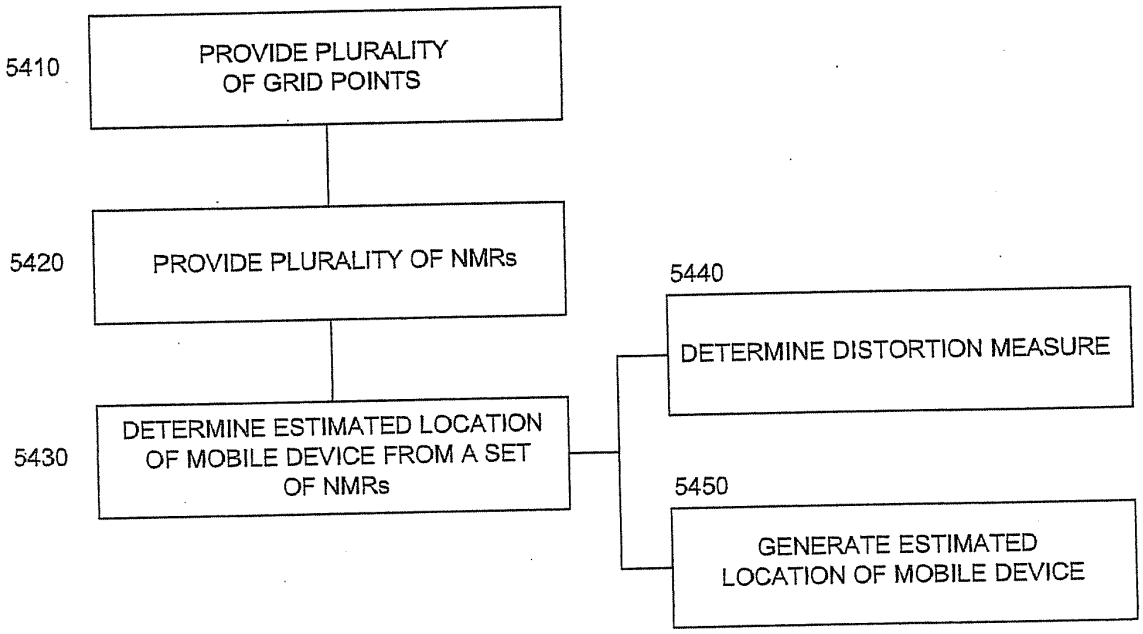

5410
PROVIDE PLURALITY OF GRID POINTS
5420
PROVIDE PLURALITY OF NMRs
5430
DETERMINE ESTIMATED LOCATION OF MOBILE DEVICE FROM A SET OF NMRs
5440
DETERMINE DISTORTION MEASURE
5450
GENERATE ESTIMATED LOCATION OF MOBILE DEVICE

FIG. 54

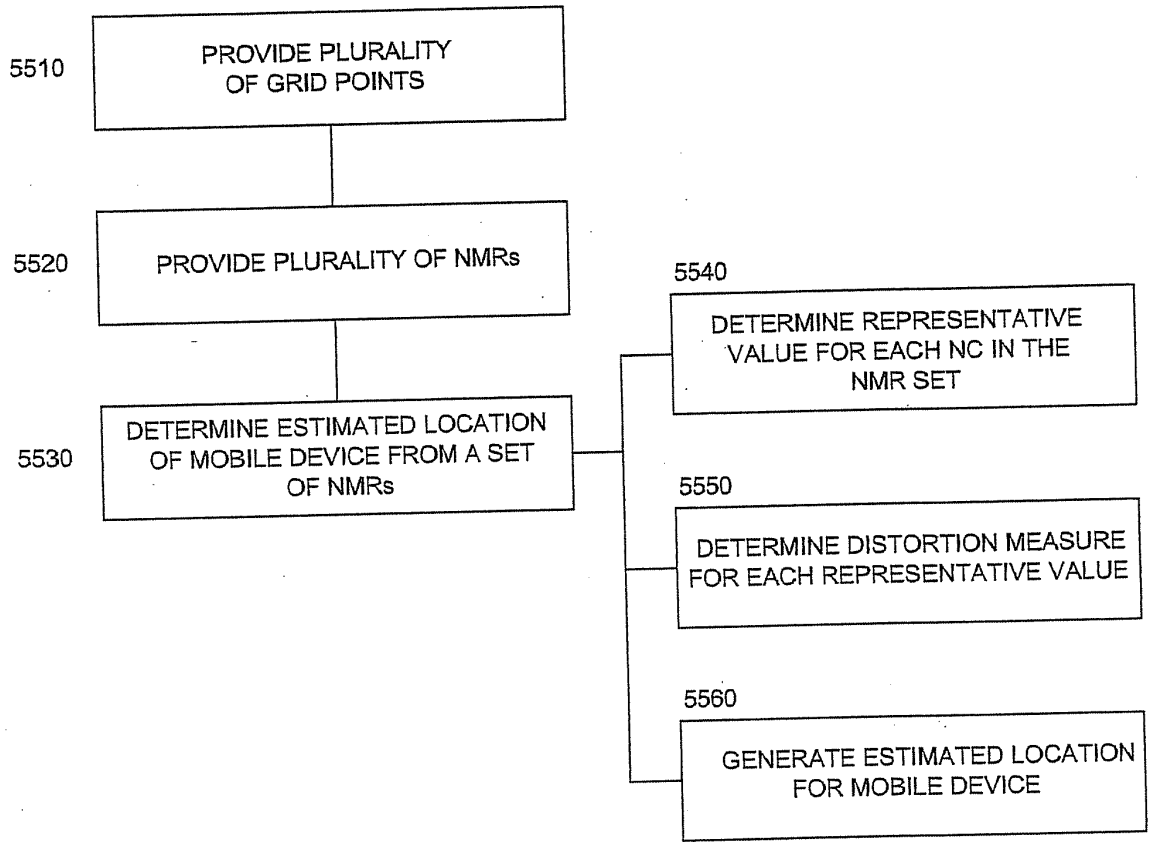

5510
PROVIDE PLURALITY OF GRID POINTS
5520
PROVIDE PLURALITY OF NMRs
5530
DETERMINE ESTIMATED LOCATION OF MOBILE DEVICE FROM A SET OF NMRs
5540
DETERMINE REPRESENTATIVE VALUE FOR EACH NC IN THE NMR SET
5550
DETERMINE DISTORTION MEASURE FOR EACH REPRESENTATIVE VALUE
5560
GENERATE ESTIMATED LOCATION FOR MOBILE DEVICE

FIG. 55

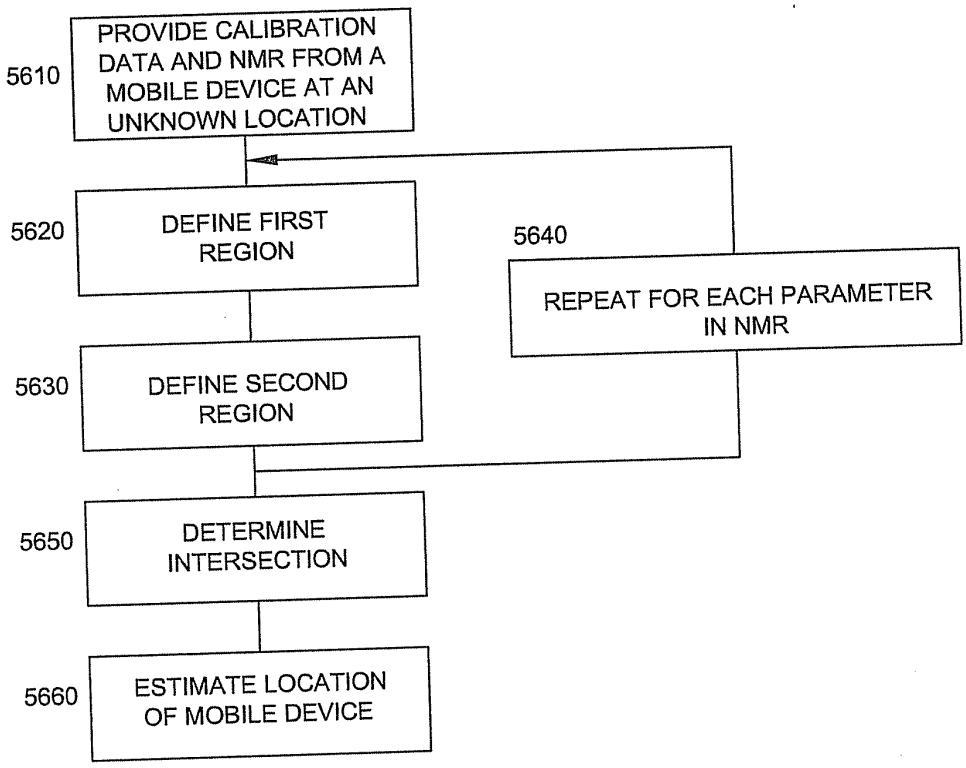

5610
PROVIDE CALIBRATION DATA AND NMR FROM A MOBILE DEVICE AT AN UNKNOWN LOCATION
5620
DEFINE FIRST REGION
5630
DEFINE SECOND REGION
5640
REPEAT FOR EACH PARAMETER IN NMR
5650
DETERMINE INTERSECTION
5660
ESTIMATE LOCATION OF MOBILE DEVICE

FIG. 56

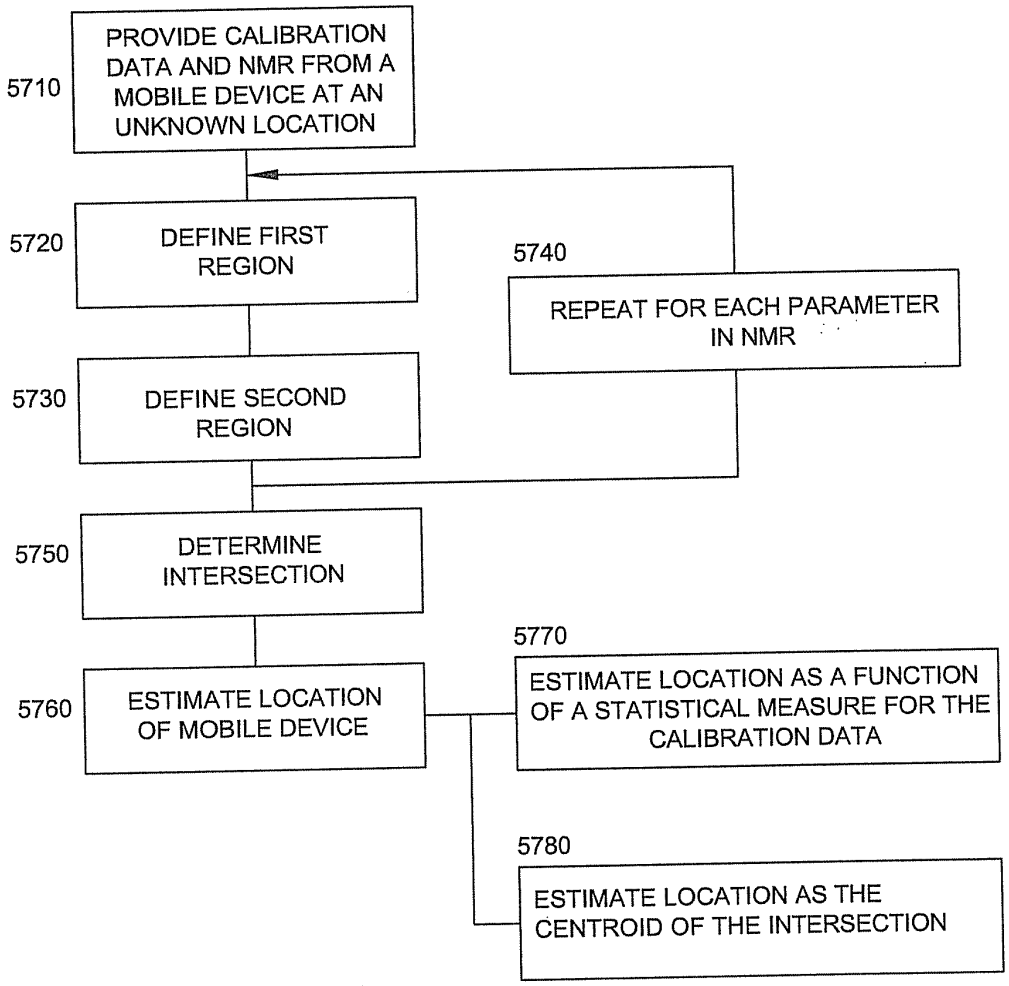

5710
PROVIDE CALIBRATION DATA AND NMR FROM A MOBILE DEVICE AT AN UNKNOWN LOCATION
5720
DEFINE FIRST REGION
5740
REPEAT FOR EACH PARAMETER IN NMR
5730
DEFINE SECOND REGION
5750
DETERMINE INTERSECTION
5770
5760
ESTIMATE LOCATION OF MOBILE DEVICE
ESTIMATE LOCATION AS A FUNCTION OF A STATISTICAL MEASURE FOR THE CALIBRATION DATA
5780
ESTIMATE LOCATION AS THE CENTROID OF THE INTERSECTION

FIG. 57

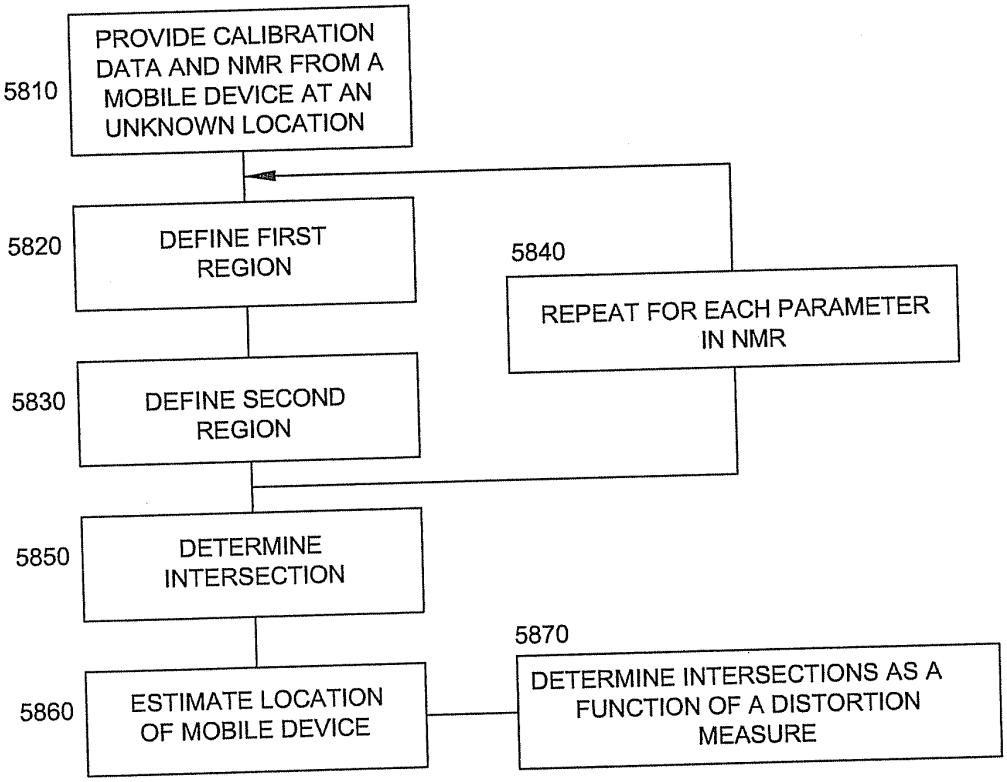

5810
PROVIDE CALIBRATION DATA AND NMR FROM A MOBILE DEVICE AT AN UNKNOWN LOCATION
5820
DEFINE FIRST REGION
5830
DEFINE SECOND REGION
5840
REPEAT FOR EACH PARAMETER IN NMR
5850
DETERMINE INTERSECTION
5860
ESTIMATE LOCATION OF MOBILE DEVICE
5870
DETERMINE INTERSECTIONS AS A FUNCTION OF A DISTORTION MEASURE

FIG. 58

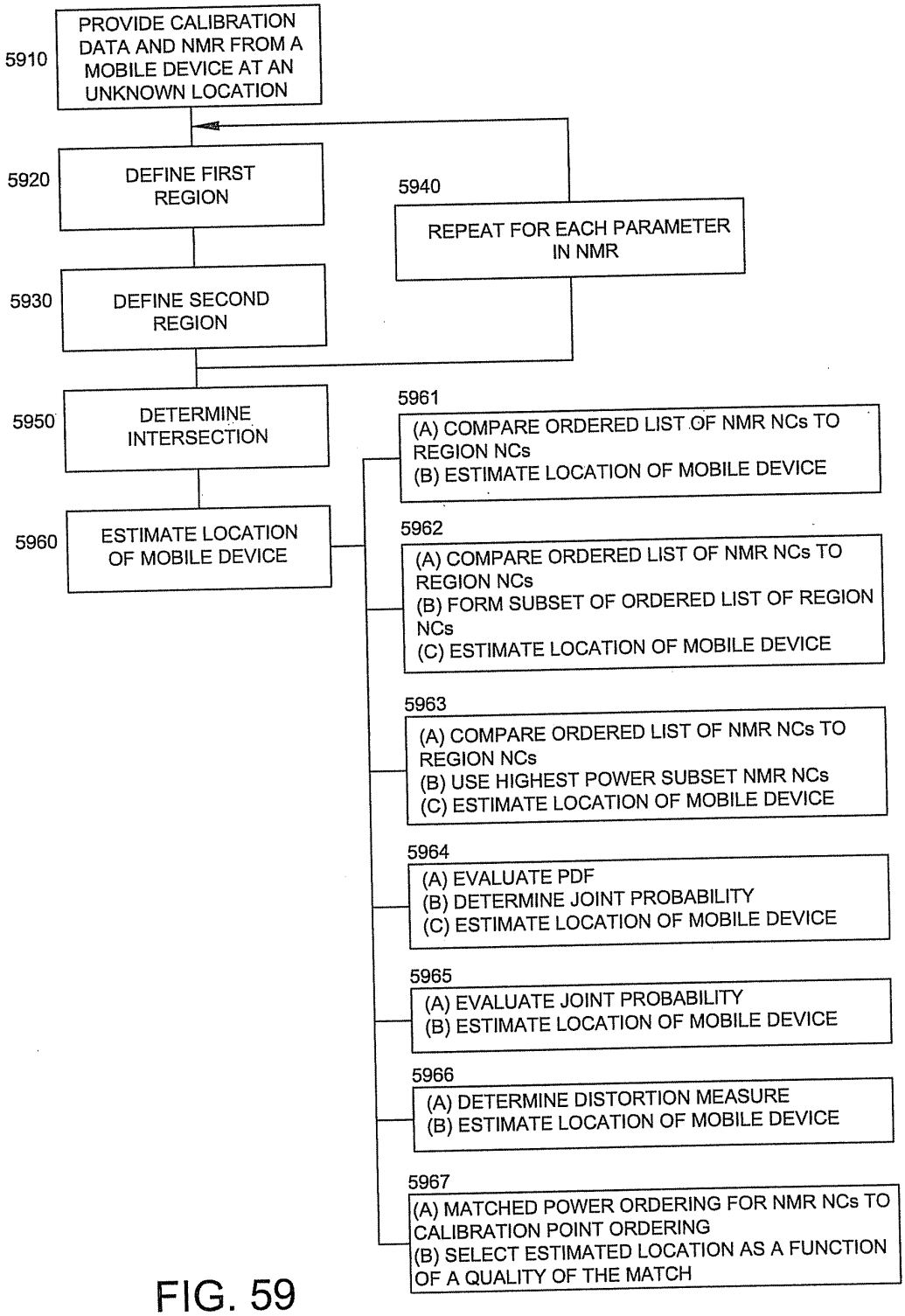

5910
PROVIDE CALIBRATION DATA AND NMR FROM A MOBILE DEVICE AT AN UNKNOWN LOCATION
5920
DEFINE FIRST REGION
5930
DEFINE SECOND REGION
5940
REPEAT FOR EACH PARAMETER IN NMR
5950
DETERMINE INTERSECTION
5960
ESTIMATE LOCATION OF MOBILE DEVICE
5961
(A) COMPARE ORDERED LIST OF NMR NCs TO REGION NCs
(B) ESTIMATE LOCATION OF MOBILE DEVICE
5962
(A) COMPARE ORDERED LIST OF NMR NCs TO REGION NCs
(B) FORM SUBSET OF ORDERED LIST OF REGION NCs
(C) ESTIMATE LOCATION OF MOBILE DEVICE
5963
(A) COMPARE ORDERED LIST OF NMR NCs TO REGION NCs
(B) USE HIGHEST POWER SUBSET NMR NCs
(C) ESTIMATE LOCATION OF MOBILE DEVICE
5964
(A) EVALUATE PDF
(B) DETERMINE JOINT PROBABILITY
(C) ESTIMATE LOCATION OF MOBILE DEVICE
5965
(A) EVALUATE JOINT PROBABILITY
(B) ESTIMATE LOCATION OF MOBILE DEVICE
5966
(A) DETERMINE DISTORTION MEASURE
(B) ESTIMATE LOCATION OF MOBILE DEVICE
5967
(A) MATCHED POWER ORDERING FOR NMR NCs TO CALIBRATION POINT ORDERING
(B) SELECT ESTIMATED LOCATION AS A FUNCTION OF A QUALITY OF THE MATCH

FIG. 59

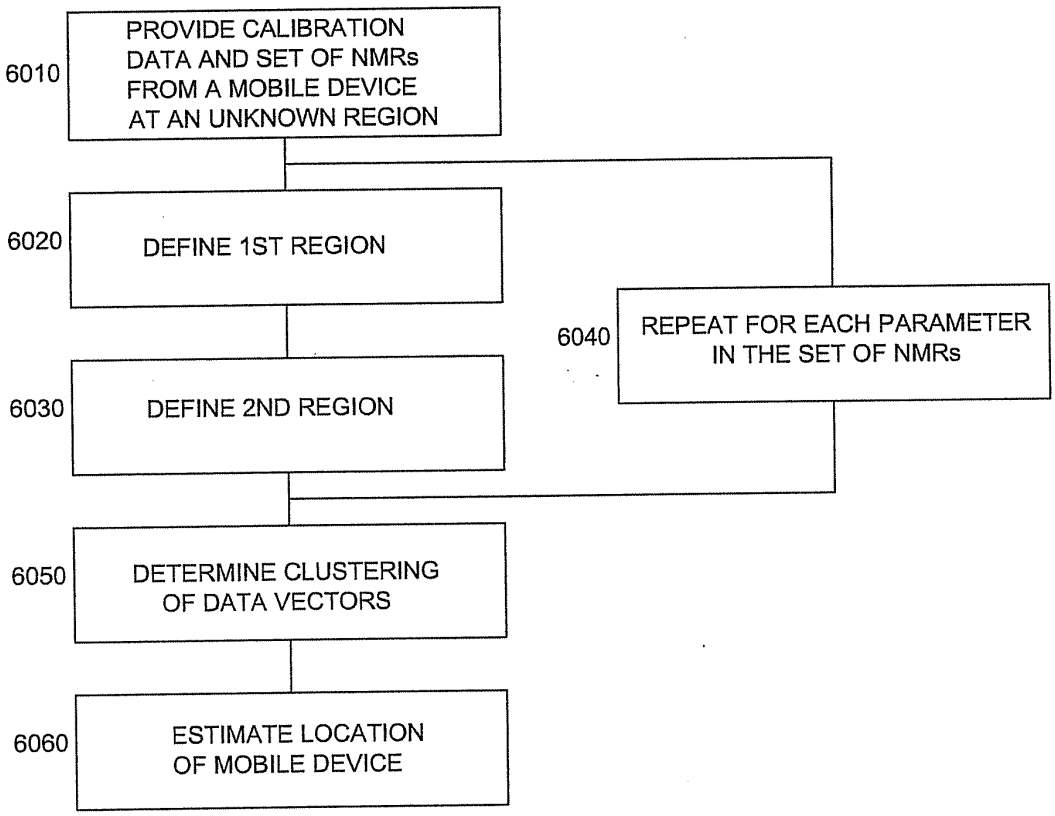

6010
PROVIDE CALIBRATION DATA AND SET OF NMRs FROM A MOBILE DEVICE AT AN UNKNOWN REGION
6020
DEFINE 1ST REGION
6030
DEFINE 2ND REGION
6040
REPEAT FOR EACH PARAMETER IN THE SET OF NMRs
6050
DETERMINE CLUSTERING OF DATA VECTORS
6060
ESTIMATE LOCATION OF MOBILE DEVICE

FIG. 60

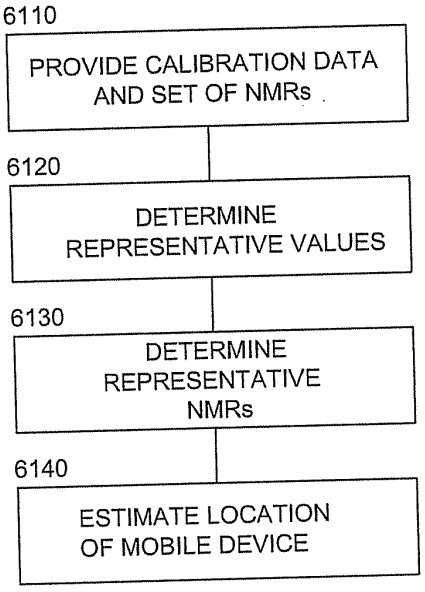

6110
PROVIDE CALIBRATION DATA AND SET OF NMRs
6120
DETERMINE REPRESENTATIVE VALUES
6130
DETERMINE REPRESENTATIVE NMRs
6140
ESTIMATE LOCATION OF MOBILE DEVICE

FIG. 61

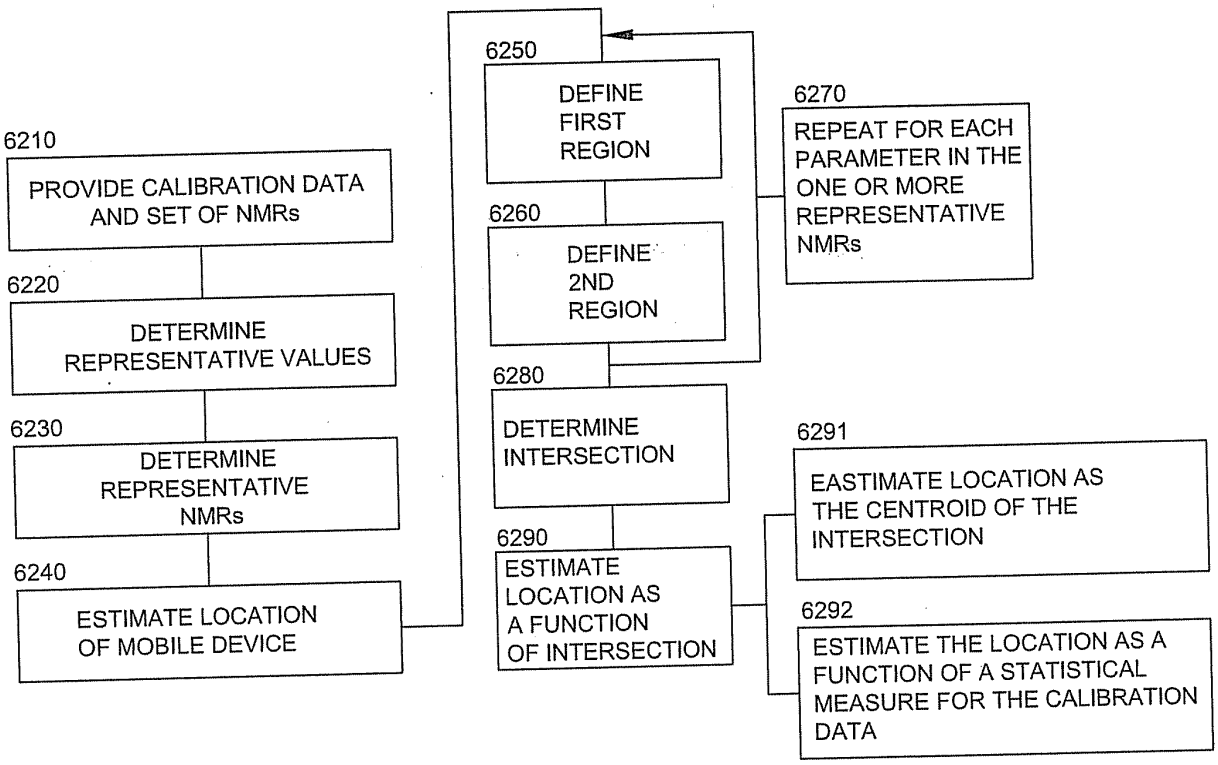

6210
PROVIDE CALIBRATION DATA AND SET OF NMRs
6220
DETERMINE REPRESENTATIVE VALUES
6230
DETERMINE REPRESENTATIVE NMRs
6240
ESTIMATE LOCATION OF MOBILE DEVICE
6250
DEFINE FIRST REGION
6260
DEFINE 2ND REGION
6270
REPEAT FOR EACH PARAMETER IN THE ONE OR MORE REPRESENTATIVE NMRs
6280
DETERMINE INTERSECTION
6290
ESTIMATE LOCATION AS A FUNCTION OF INTERSECTION
6291
EASTIMATE LOCATION AS THE CENTROID OF THE INTERSECTION
6292
ESTIMATE THE LOCATION AS A FUNCTION OF A STATISTICAL MEASURE FOR THE CALIBRATION DATA

FIG. 62

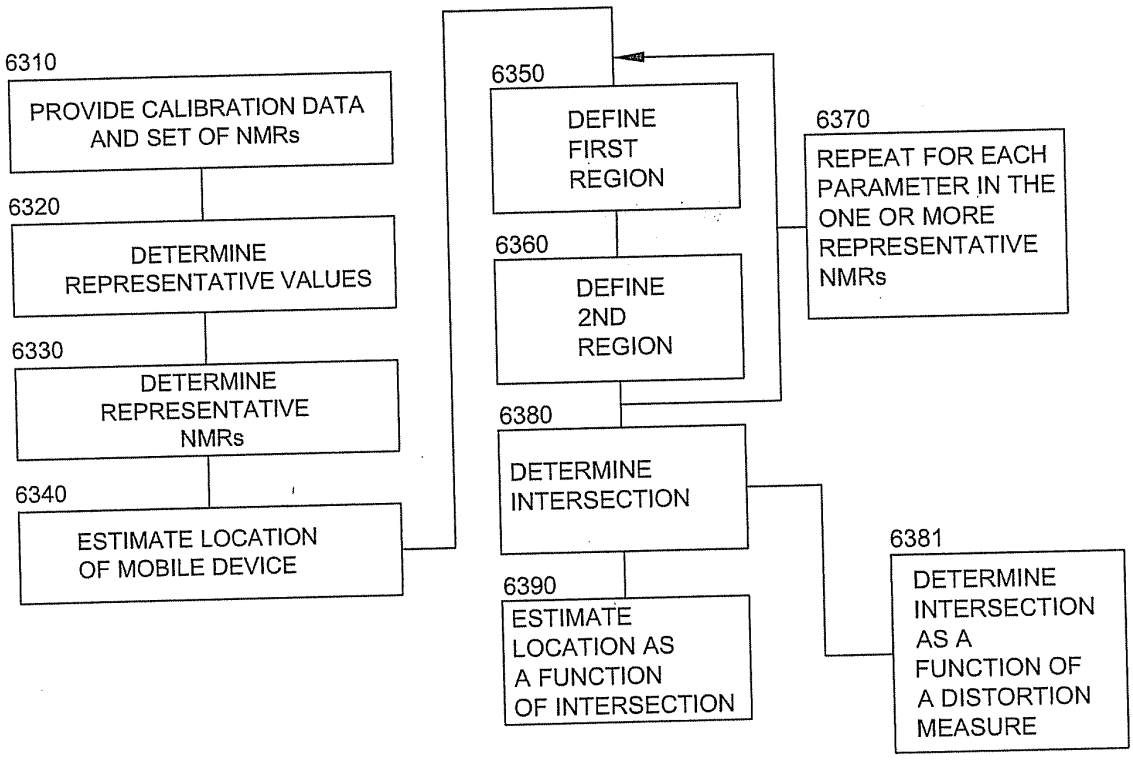

6310
PROVIDE CALIBRATION DATA AND SET OF NMRs
6320
DETERMINE REPRESENTATIVE VALUES
6330
DETERMINE REPRESENTATIVE NMRs
6340
ESTIMATE LOCATION OF MOBILE DEVICE
6350
DEFINE FIRST REGION
6360
DEFINE 2ND REGION
6370
REPEAT FOR EACH PARAMETER IN THE ONE OR MORE REPRESENTATIVE NMRs
6380
DETERMINE INTERSECTION
6381
DETERMINE INTERSECTION AS A FUNCTION OF A DISTORTION MEASURE
6390
ESTIMATE LOCATION AS A FUNCTION OF INTERSECTION

FIG. 63

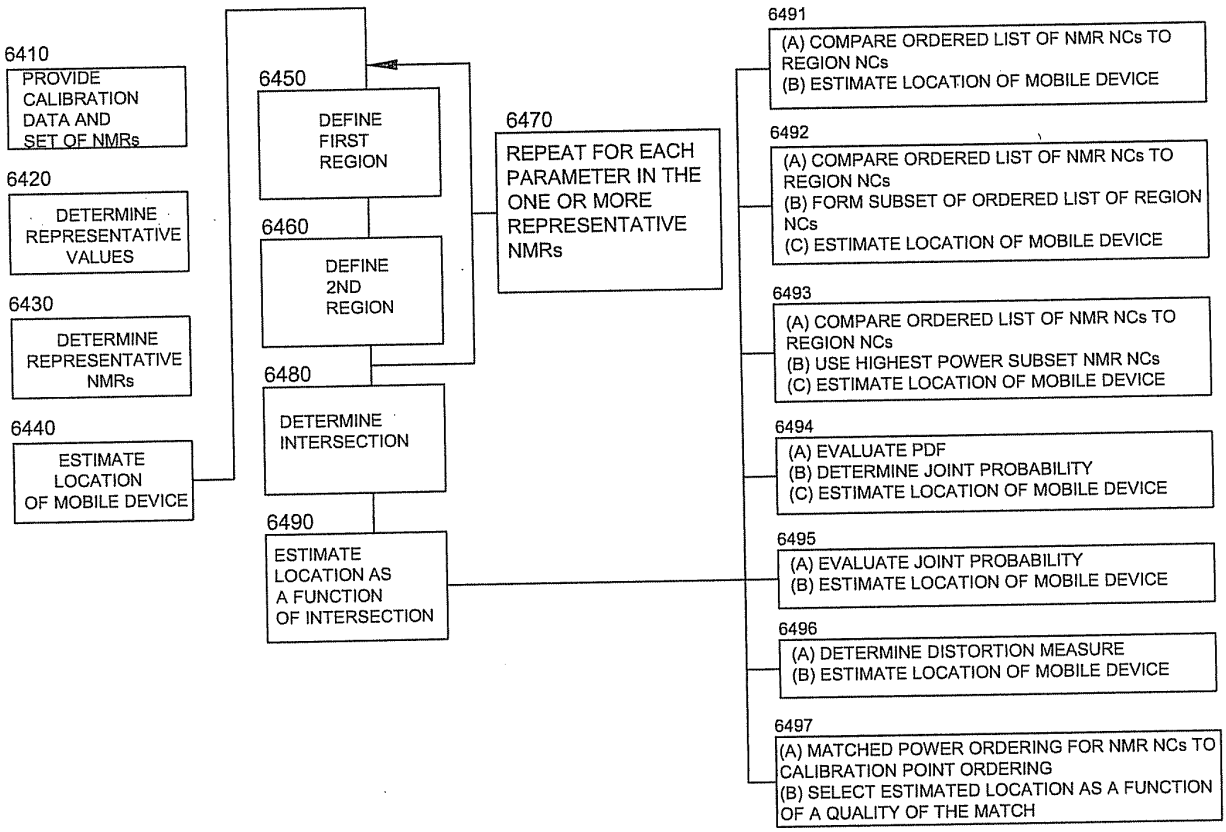

6410
PROVIDE CALIBRATION DATA AND SET OF NMRs
6420
DETERMINE REPRESENTATIVE VALUES
6430
DETERMINE REPRESENTATIVE NMRs
6440
ESTIMATE LOCATION OF MOBILE DEVICE
6450
DEFINE FIRST REGION
6460
DEFINE 2ND REGION
6470
REPEAT FOR EACH PARAMETER IN THE ONE OR MORE REPRESENTATIVE NMRs
6480
DETERMINE INTERSECTION
6490
ESTIMATE LOCATION AS A FUNCTION OF INTERSECTION
6491
(A) COMPARE ORDERED LIST OF NMR NCs TO REGION NCs
(B) ESTIMATE LOCATION OF MOBILE DEVICE
6492
(A) COMPARE ORDERED LIST OF NMR NCs TO REGION NCs
(B) FORM SUBSET OF ORDERED LIST OF REGION NCs
(C) ESTIMATE LOCATION OF MOBILE DEVICE
6493
(A) COMPARE ORDERED LIST OF NMR NCs TO REGION NCs
(B) USE HIGHEST POWER SUBSET NMR NCs
(C) ESTIMATE LOCATION OF MOBILE DEVICE
6494
(A) EVALUATE PDF
(B) DETERMINE JOINT PROBABILITY
(C) ESTIMATE LOCATION OF MOBILE DEVICE
6495
(A) EVALUATE JOINT PROBABILITY
(B) ESTIMATE LOCATION OF MOBILE DEVICE
6496
(A) DETERMINE DISTORTION MEASURE
(B) ESTIMATE LOCATION OF MOBILE DEVICE
6497
(A) MATCHED POWER ORDERING FOR NMR NCs TO CALIBRATION POINT ORDERING
(B) SELECT ESTIMATED LOCATION AS A FUNCTION OF A QUALITY OF THE MATCH

FIG. 64

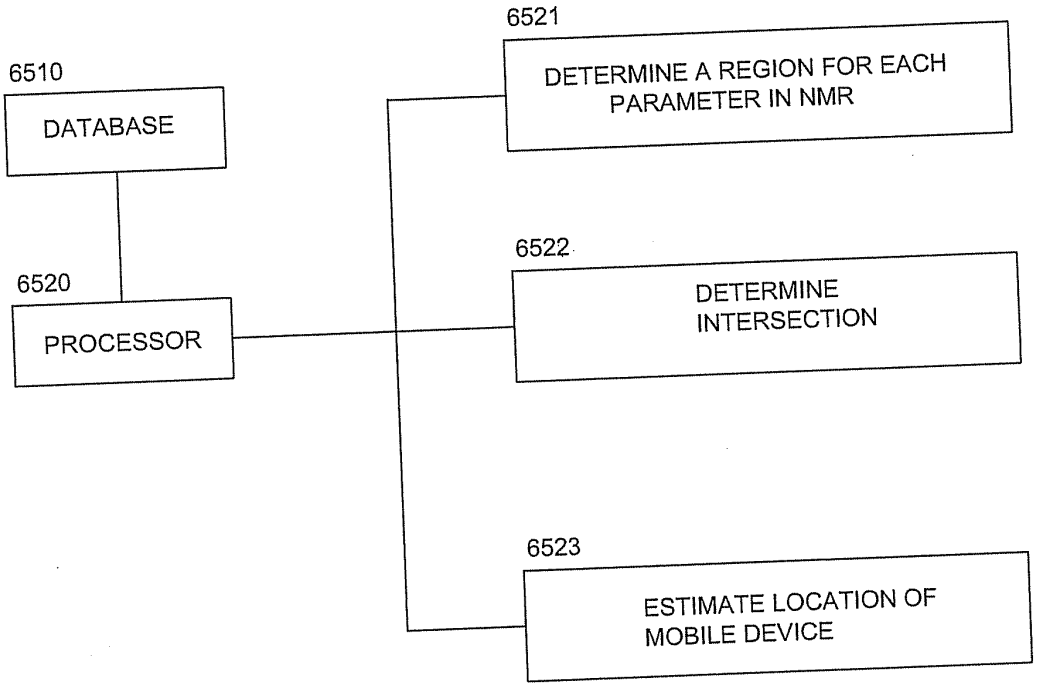

6510
DATABASE
6520
PROCESSOR
6521
DETERMINE A REGION FOR EACH PARAMETER IN NMR
6522
DETERMINE INTERSECTION
6523
ESTIMATE LOCATION OF MOBILE DEVICE

FIG. 65

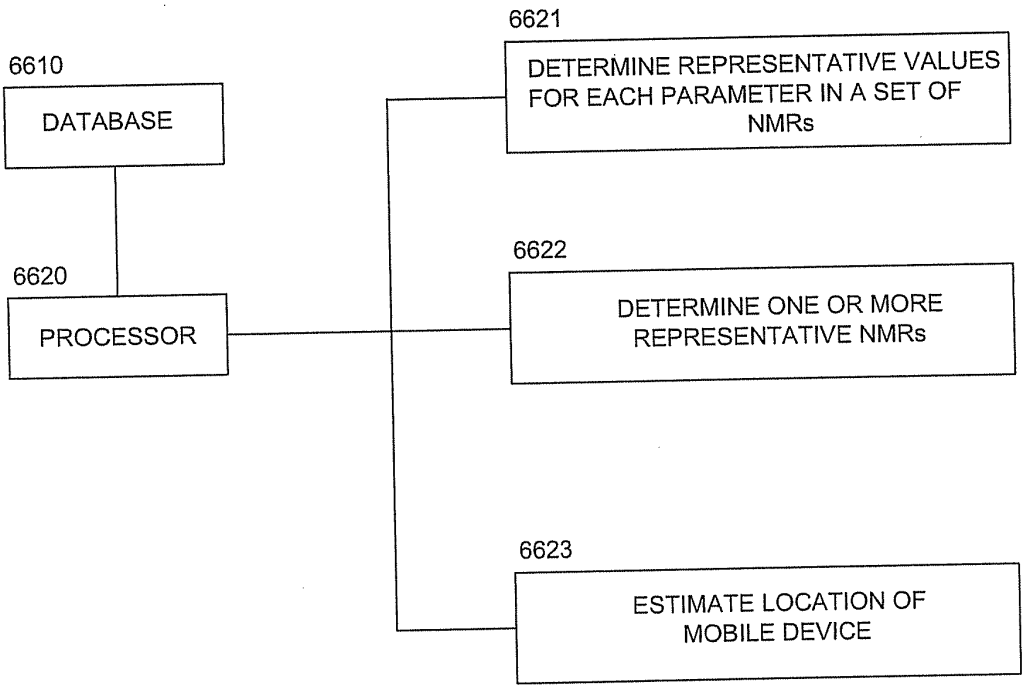

6610
DATABASE
6620
PROCESSOR
6621
DETERMINE REPRESENTATIVE VALUES FOR EACH PARAMETER IN A SET OF NMRs
6622
DETERMINE ONE OR MORE REPRESENTATIVE NMRs
6623
ESTIMATE LOCATION OF MOBILE DEVICE

FIG. 66

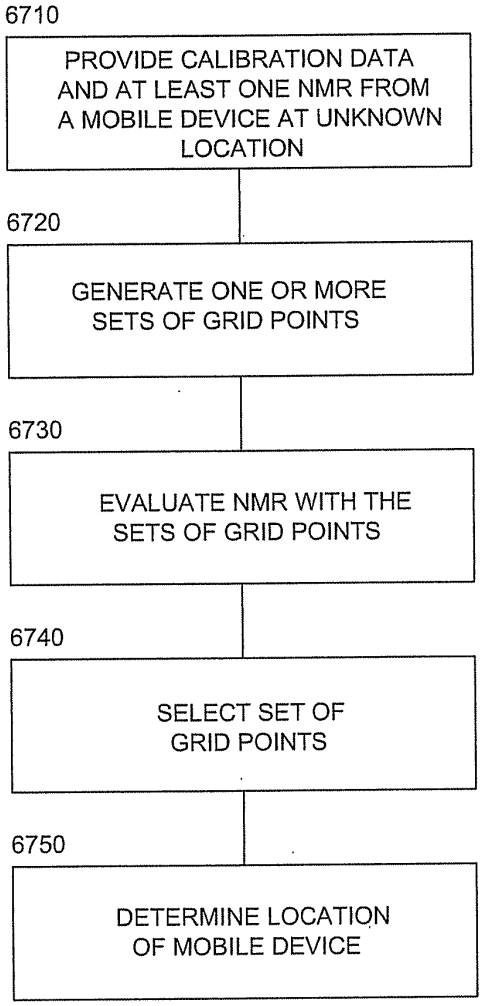

6710
PROVIDE CALIBRATION DATA AND AT LEAST ONE NMR FROM A MOBILE DEVICE AT UNKNOWN LOCATION
6720
GENERATE ONE OR MORE SETS OF GRID POINTS
6730
EVALUATE NMR WITH THE SETS OF GRID POINTS
6740
SELECT SET OF GRID POINTS
6750
DETERMINE LOCATION OF MOBILE DEVICE

FIG. 67

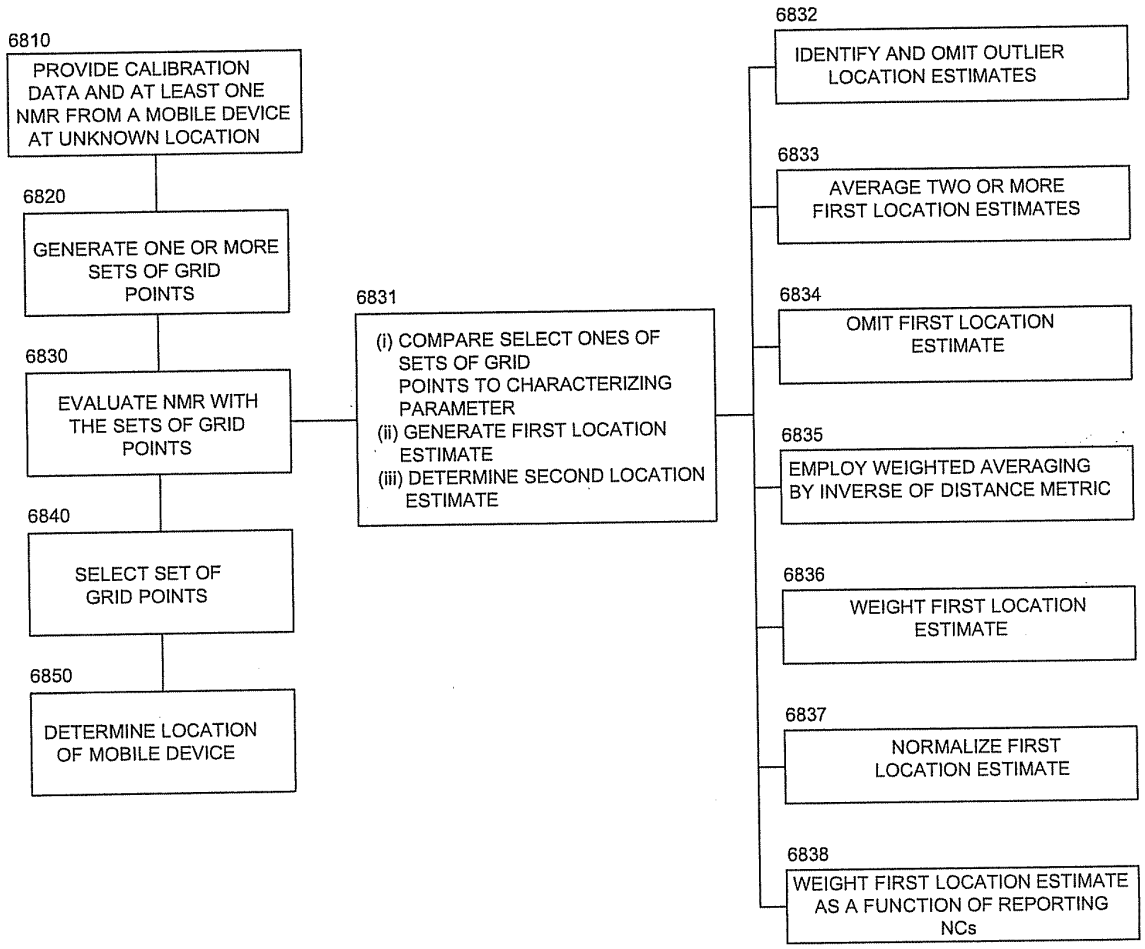

6810
PROVIDE CALIBRATION DATA AND AT LEAST ONE NMR FROM A MOBILE DEVICE AT UNKNOWN LOCATION
6820
GENERATE ONE OR MORE SETS OF GRID POINTS
6830
EVALUATE NMR WITH THE SETS OF GRID POINTS
6840
SELECT SET OF GRID POINTS
6850
DETERMINE LOCATION OF MOBILE DEVICE
6831
(i) COMPARE SELECT ONES OF SETS OF GRID POINTS TO CHARACTERIZING PARAMETER
(ii) GENERATE FIRST LOCATION ESTIMATE
(iii) DETERMINE SECOND LOCATION ESTIMATE
6832
IDENTIFY AND OMIT OUTLIER LOCATION ESTIMATES
6833
AVERAGE TWO OR MORE FIRST LOCATION ESTIMATES
6834
OMIT FIRST LOCATION ESTIMATE
6835
EMPLOY WEIGHTED AVERAGING BY INVERSE OF DISTANCE METRIC
6836
WEIGHT FIRST LOCATION ESTIMATE
6837
NORMALIZE FIRST LOCATION ESTIMATE
6838
WEIGHT FIRST LOCATION ESTIMATE AS A FUNCTION OF REPORTING NCs

FIG. 68

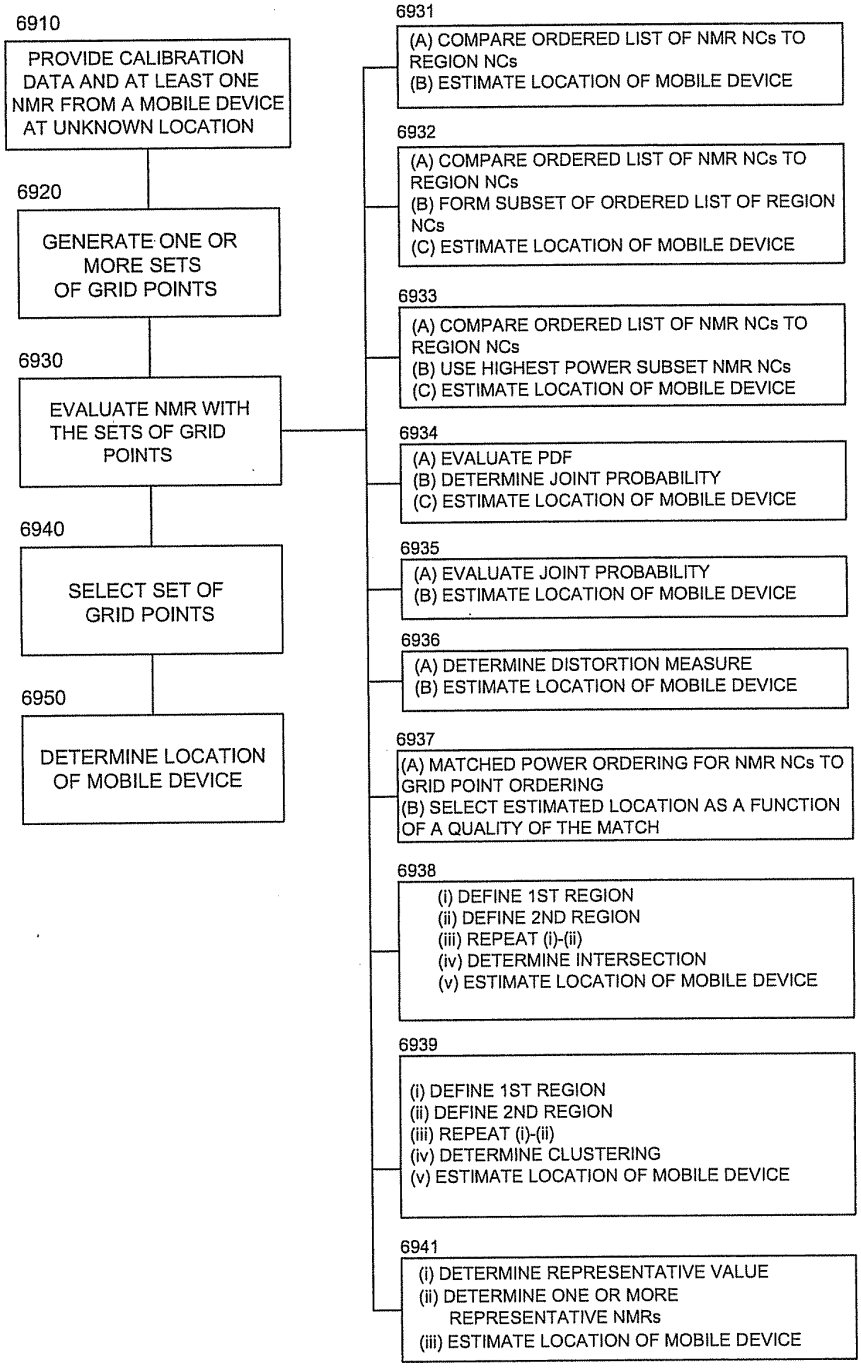

6910
PROVIDE CALIBRATION DATA AND AT LEAST ONE NMR FROM A MOBILE DEVICE AT UNKNOWN LOCATION
6920
GENERATE ONE OR MORE SETS OF GRID POINTS
6930
EVALUATE NMR WITH THE SETS OF GRID POINTS
6940
SELECT SET OF GRID POINTS
6950
DETERMINE LOCATION OF MOBILE DEVICE
6931
(A) COMPARE ORDERED LIST OF NMR NCs TO REGION NCs
(B) ESTIMATE LOCATION OF MOBILE DEVICE
6932
(A) COMPARE ORDERED LIST OF NMR NCs TO REGION NCs
(B) FORM SUBSET OF ORDERED LIST OF REGION NCs
(C) ESTIMATE LOCATION OF MOBILE DEVICE
6933
(A) COMPARE ORDERED LIST OF NMR NCs TO REGION NCs
(B) USE HIGHEST POWER SUBSET NMR NCs
(C) ESTIMATE LOCATION OF MOBILE DEVICE
6934
(A) EVALUATE PDF
(B) DETERMINE JOINT PROBABILITY
(C) ESTIMATE LOCATION OF MOBILE DEVICE
6935
(A) EVALUATE JOINT PROBABILITY
(B) ESTIMATE LOCATION OF MOBILE DEVICE
6936
(A) DETERMINE DISTORTION MEASURE
(B) ESTIMATE LOCATION OF MOBILE DEVICE
6937
(A) MATCHED POWER ORDERING FOR NMR NCs TO GRID POINT ORDERING
(B) SELECT ESTIMATED LOCATION AS A FUNCTION OF A QUALITY OF THE MATCH
6938
(i) DEFINE 1ST REGION
(ii) DEFINE 2ND REGION
(iii) REPEAT (i)-(ii)
(iv) DETERMINE INTERSECTION
(v) ESTIMATE LOCATION OF MOBILE DEVICE
6939
(i) DEFINE 1ST REGION
(ii) DEFINE 2ND REGION
(iii) REPEAT (i)-(ii)
(iv) DETERMINE CLUSTERING
(v) ESTIMATE LOCATION OF MOBILE DEVICE
6941
(i) DETERMINE REPRESENTATIVE VALUE
(ii) DETERMINE ONE OR MORE REPRESENTATIVE NMRs
(iii) ESTIMATE LOCATION OF MOBILE DEVICE

FIG. 69

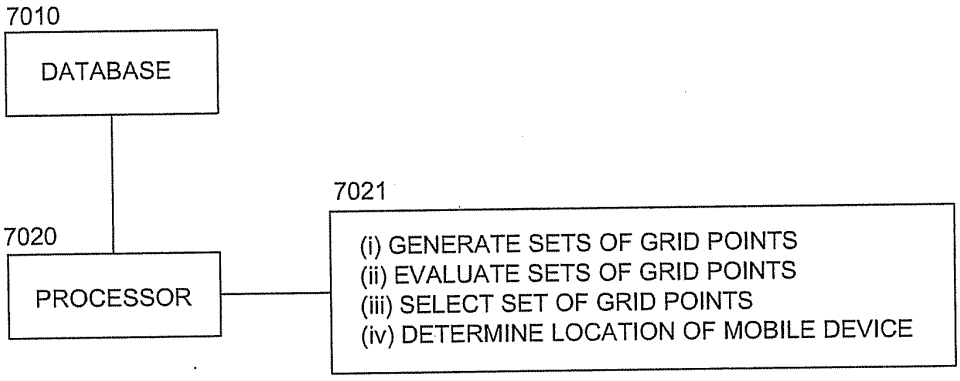

7010
DATABASE
7020
PROCESSOR
7021
(i) GENERATE SETS OF GRID POINTS
(ii) EVALUATE SETS OF GRID POINTS
(iii) SELECT SET OF GRID POINTS
(iv) DETERMINE LOCATION OF MOBILE DEVICE

FIG. 70

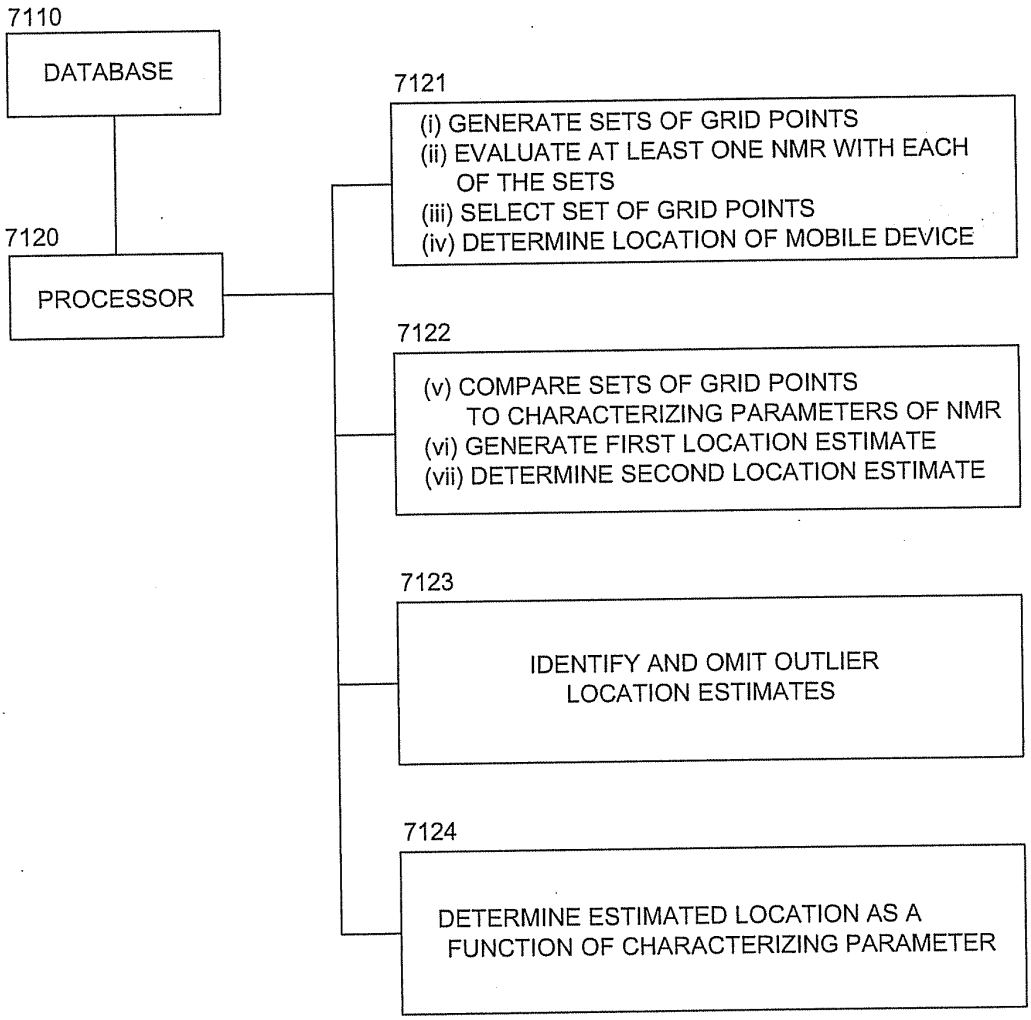

7110
DATABASE
7120
PROCESSOR
7121
(i) GENERATE SETS OF GRID POINTS
(ii) EVALUATE AT LEAST ONE NMR WITH EACH OF THE SETS
(iii) SELECT SET OF GRID POINTS
(iv) DETERMINE LOCATION OF MOBILE DEVICE
7122
(v) COMPARE SETS OF GRID POINTS TO CHARACTERIZING PARAMETERS OF NMR
(vi) GENERATE FIRST LOCATION ESTIMATE
(vii) DETERMINE SECOND LOCATION ESTIMATE
7123
IDENTIFY AND OMIT OUTLIER LOCATION ESTIMATES
7124
DETERMINE ESTIMATED LOCATION AS A FUNCTION OF CHARACTERIZING PARAMETER

FIG. 71

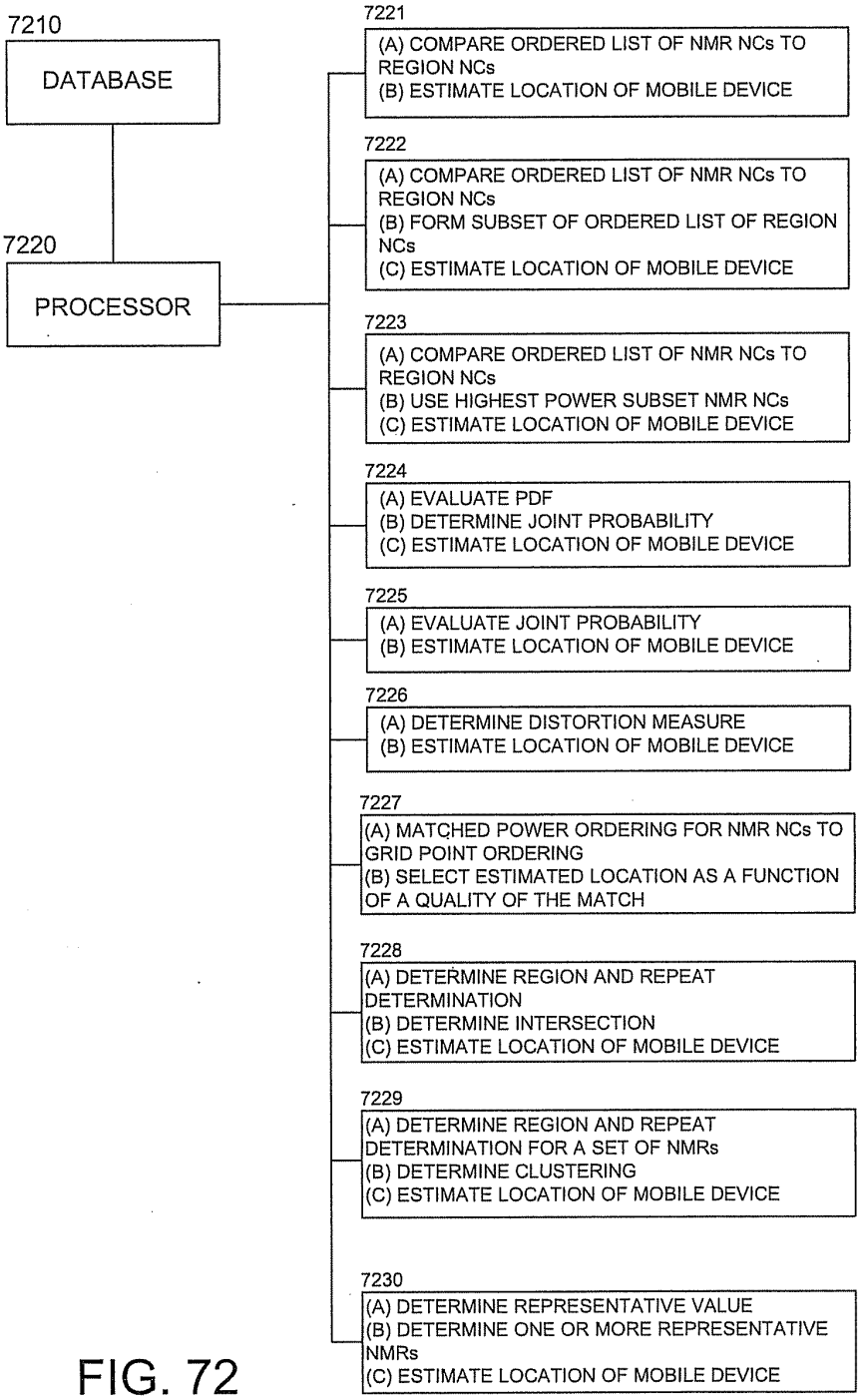

7210
DATABASE
7220
PROCESSOR
7221
(A) COMPARE ORDERED LIST OF NMR NCs TO REGION NCs
(B) ESTIMATE LOCATION OF MOBILE DEVICE
7222
(A) COMPARE ORDERED LIST OF NMR NCs TO REGION NCs
(B) FORM SUBSET OF ORDERED LIST OF REGION NCs
(C) ESTIMATE LOCATION OF MOBILE DEVICE
7223
(A) COMPARE ORDERED LIST OF NMR NCs TO REGION NCs
(B) USE HIGHEST POWER SUBSET NMR NCs
(C) ESTIMATE LOCATION OF MOBILE DEVICE
7224
(A) EVALUATE PDF
(B) DETERMINE JOINT PROBABILITY
(C) ESTIMATE LOCATION OF MOBILE DEVICE
7225
(A) EVALUATE JOINT PROBABILITY
(B) ESTIMATE LOCATION OF MOBILE DEVICE
7226
(A) DETERMINE DISTORTION MEASURE
(B) ESTIMATE LOCATION OF MOBILE DEVICE
7227
(A) MATCHED POWER ORDERING FOR NMR NCs TO GRID POINT ORDERING
(B) SELECT ESTIMATED LOCATION AS A FUNCTION OF A QUALITY OF THE MATCH
7228
(A) DETERMINE REGION AND REPEAT DETERMINATION
(B) DETERMINE INTERSECTION
(C) ESTIMATE LOCATION OF MOBILE DEVICE
7229
(A) DETERMINE REGION AND REPEAT DETERMINATION FOR A SET OF NMRs
(B) DETERMINE CLUSTERING
(C) ESTIMATE LOCATION OF MOBILE DEVICE
7230
(A) DETERMINE REPRESENTATIVE VALUE
(B) DETERMINE ONE OR MORE REPRESENTATIVE NMRs
(C) ESTIMATE LOCATION OF MOBILE DEVICE

FIG. 72

Electronic Patent Application Fee Transmittal

Application Number:	
Filing Date:	
Title of Invention:	SYSTEM AND METHOD FOR GENERATING A LOCATION ESTIMATE USING UNIFORM AND NON-UNIFORM GRID POINTS
First Named Inventor/Applicant Name:	Martin ALLES
Filer:	Mark Charles Comtois/Josh Staples
Attorney Docket Number:	AND01 080
Filed as Large Entity	

Utility Filing Fees

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Basic Filing:				
Utility application filing	1011	1	310	310
Utility Search Fee	1111	1	510	510
Utility Examination Fee	1311	1	210	210
Pages:				
Utility Appl Size fee per 50 sheets >100	1081	1	260	260
Claims:				
Claims in excess of 20	1202	37	50	1850
Miscellaneous-Filing:				

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Petition:				
Patent-Appeals-and-Interference:				
Post-Allowance-and-Post-Issuance:				
Extension-of-Time:				
Miscellaneous:				
		Total in USD ($)		**3140**

Electronic Acknowledgement Receipt	
EFS ID:	2819105
Application Number:	12026480
International Application Number:	
Confirmation Number:	3162
Title of Invention:	SYSTEM AND METHOD FOR GENERATING A LOCATION ESTIMATE USING UNIFORM AND NON-UNIFORM GRID POINTS
First Named Inventor/Applicant Name:	Martin ALLES
Customer Number:	39290
Filer:	Mark Charles Comtois/Josh Staples
Filer Authorized By:	Mark Charles Comtois
Attorney Docket Number:	AND01 080
Receipt Date:	05-FEB-2008
Filing Date:	
Time Stamp:	19:51:42
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	yes
Payment Type	Deposit Account
Payment was successfully received in RAM	$3140
RAM confirmation Number	3837
Deposit Account	041679
Authorized User	
The Director of the USPTO is hereby authorized to charge indicated fees and credit any overpayment as follows: Charge any Additional Fees required under 37 C.F.R. Section 1.16 (National application filing, search, and examination fees) Charge any Additional Fees required under 37 C.F.R. Section 1.21 (Miscellaneous fees and charges)	

File Listing:

Document Number	Document Description	File Name	File Size(Bytes) /Message Digest	Multi Part /.zip	Pages (if appl.)
1		AND01080application1of3.pdf	941819 bcf64da1c623022f9e85c6957190ecb52721ff36	yes	6

Multipart Description/PDF files in .zip description		
Document Description	**Start**	**End**
Transmittal of New Application	1	1
Fee Worksheet (PTO-06)	2	2
Application Data Sheet	3	6

Warnings:

Information:

2		AND01080application2of3.pdf	8945582 69f8bec22de8f2f20786d9696c0528b287827f16	yes	122

Multipart Description/PDF files in .zip description		
Document Description	**Start**	**End**
Specification	1	102
Claims	103	121
Abstract	122	122

Warnings:

Information:

3	Drawings-only black and white line drawings	AND01080application3of3.pdf	2425009 5cecaf54e0dacd043496738079b4872bd21d5777	no	72

Warnings:

Information:

4	Fee Worksheet (PTO-06)	fee-info.pdf	8607 e9bd7705036df2c359dc063569ede98d239249c0	no	2

Warnings:

Information:

Total Files Size (in bytes):	12321017

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New Applications Under 35 U.S.C. 111
If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.

National Stage of an International Application under 35 U.S.C. 371
If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.

New International Application Filed with the USPTO as a Receiving Office
If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

PTO/SB/05 (07-07)
Approved for use through 06/30/2010. OMB 0651-0032
U.S. Patent and Trademark Office. U.S. DEPARTMENT OF COMMERCE
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UTILITY PATENT APPLICATION TRANSMITTAL

(Only for new nonprovisional applications under 37 CFR 1.53(b))

Attorney Docket No.	AND01 080
First Inventor	Martin ALLES
Title	SYSTEM AND METHOD FOR GENERATIN
Express Mail Label No.	

APPLICATION ELEMENTS

See MPEP chapter 600 concerning utility patent application contents.

1. ☑ **Fee Transmittal Form** (e.g., PTO/SB/17)
   (Submit an original and a duplicate for fee processing)
2. ☐ **Applicant claims small entity status.**
   See 37 CFR 1.27.
3. ☑ **Specification** [*Total Pages* 122]
   Both the claims and abstract must start on a new page
   (For information on the preferred arrangement, see MPEP 608.01(a))
4. ☑ **Drawing(s)** (*35 U.S.C. 113*) [*Total Sheets* 72]
5. **Oath or Declaration** [*Total Sheets* _____]
   a. ☐ Newly executed (original or copy)
   b. ☐ A copy from a prior application (37 CFR 1.63(d))
   (for continuation/divisional with Box 18 completed)
   i. ☐ DELETION OF INVENTOR(S)
   Signed statement attached deleting inventor(s) name in the prior application, see 37 CFR 1.63(d)(2) and 1.33(b).
6. ☑ **Application Data Sheet.** See 37 CFR 1.76
7. ☐ **CD-ROM or CD-R** in duplicate, large table or Computer Program *(Appendix)*
   ☐ Landscape Table on CD
8. **Nucleotide and/or Amino Acid Sequence Submission**
   (if applicable, items a. – c. are required)
   a. ☐ Computer Readable Form (CRF)
   b. Specification Sequence Listing on:
      i. ☐ CD-ROM or CD-R (2 copies); or
      ii. ☐ Paper
   c. ☐ Statements verifying identity of above copies

ADDRESS TO:

Commissioner for Patents
P.O. Box 1450
Alexandria VA 22313-1450

ACCOMPANYING APPLICATION PARTS

9. ☐ **Assignment Papers** (cover sheet & document(s))
   Name of Assignee _____
10. ☐ **37 CFR 3.73(b) Statement** *(when there is an assignee)* ☐ **Power of Attorney**
11. ☐ **English Translation Document** *(if applicable)*
12. ☐ **Information Disclosure Statement** (PTO/SB/08 or PTO-1449)
    ☐ Copies of citations attached
13. ☐ **Preliminary Amendment**
14. ☐ **Return Receipt Postcard** (MPEP 503)
    (Should be specifically itemized)
15. ☐ **Certified Copy of Priority Document(s)**
    (if foreign priority is claimed)
16. ☐ **Nonpublication Request** under 35 U.S.C. 122(b)(2)(B)(i).
    Applicant must attach form PTO/SB/35 or equivalent.
17. ☐ Other: _____

18. If a CONTINUING APPLICATION, *check appropriate box, and supply the requisite information below and in the first sentence of the specification following the title, or in an Application Data Sheet under 37 CFR 1.76:*

☐ Continuation ☐ Divisional ☐ Continuation-in-part (CIP) of prior application No.: .....

Prior application information: *Examiner* _____ *Art Unit:* _____

19. CORRESPONDENCE ADDRESS

☑ The address associated with Customer Number: 39290 ***OR*** ☐ Correspondence address below

Name	Duane Morris LLP				
Address	505 9th Street, N.W., Suite 1000				
City	Washington	State	D.C.	Zip Code	20004-2166
Country	USA	Telephone	202.776-7800	Email	

Signature	/mcc/	Date	05 February 2008
Name (Print/Type)	Mark C. Comtois	Registration No. (Attorney/Agent)	46,285

This collection of information is required by 37 CFR 1.53(b). The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.11 and 1.14. This collection is estimated to take 12 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

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PTO/SB/17 (10-07)
Approved for use through 06/30/2010. OMB 0651-0032
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
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Effective on 12/08/2004.
Fees pursuant to the Consolidated Appropriations Act, 2005 (H.R. 4818).

FEE TRANSMITTAL
For FY 2008

☐ Applicant claims small entity status. See 37 CFR 1.27

TOTAL AMOUNT OF PAYMENT ($) $3,400.00

Complete if Known	
Application Number	New Application
Filing Date	05 February 2008
First Named Inventor	Martin ALLES
Examiner Name	Unassigned
Art Unit	Unassigned
Attorney Docket No.	AND01 080

METHOD OF PAYMENT (check all that apply)

☐ Check ☐ Credit Card ☐ Money Order ☐ None ☐ Other (please identify): _____

☑ Deposit Account Deposit Account Number: 04-1679 Deposit Account Name: Duane Morris LLP

For the above-identified deposit account, the Director is hereby authorized to: (check all that apply)

☑ Charge fee(s) indicated below ☐ Charge fee(s) indicated below, **except for the filing fee**

☑ Charge any additional fee(s) or underpayments of fee(s) under 37 CFR 1.16 and 1.17 ☑ Credit any overpayments

WARNING: Information on this form may become public. Credit card information should not be included on this form. Provide credit card information and authorization on PTO-2038.

FEE CALCULATION

1. BASIC FILING, SEARCH, AND EXAMINATION FEES

	FILING FEES		SEARCH FEES		EXAMINATION FEES		
		Small Entity		Small Entity		Small Entity	
Application Type	Fee ($)	Fee ($)	Fee ($)	Fee ($)	Fee ($)	Fee ($)	Fees Paid ($)
Utility	310	155	510	255	210	105	1,030.00
Design	210	105	100	50	130	65	
Plant	210	105	310	155	160	80	
Reissue	310	155	510	255	620	310	
Provisional	210	105	0	0	0	0	

2. EXCESS CLAIM FEES

Fee Description	Fee ($)	Small Entity Fee ($)
Each claim over 20 (including Reissues)	50	25
Each independent claim over 3 (including Reissues)	210	105
Multiple dependent claims	370	185

Total Claims		Extra Claims		Fee ($)		Fee Paid ($)
57	- 20 or HP =	37	x	50.00	=	1,850.00

HP = highest number of total claims paid for, if greater than 20.

Indep. Claims		Extra Claims		Fee ($)		Fee Paid ($)
2	- 3 or HP =	0	x	0	=	0.00

HP = highest number of independent claims paid for, if greater than 3.

Multiple Dependent Claims	
Fee ($)	Fee Paid ($)

3. APPLICATION SIZE FEE

If the specification and drawings exceed 100 sheets of paper (excluding electronically filed sequence or computer listings under 37 CFR 1.52(e)), the application size fee due is $260 ($130 for small entity) for each additional 50 sheets or fraction thereof. See 35 U.S.C. 41(a)(1)(G) and 37 CFR 1.16(s).

Total Sheets		Extra Sheets		Number of each additional 50 or fraction thereof		Fee ($)		Fee Paid ($)
194	- 100 =	93	/ 50 =	2	(round **up** to a whole number) x	260.00	=	520.00

4. OTHER FEE(S)

	Fees Paid ($)
Non-English Specification, $130 fee (no small entity discount)	
Other (e.g., late filing surcharge): _____	

SUBMITTED BY

Signature	/mcc/	Registration No. (Attorney/Agent) 46,285	Telephone 202-776-7800
Name (Print/Type)	Mark C. Comtois		Date 05 February 2008

This collection of information is required by 37 CFR 1.136. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 30 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

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PTO/SB/06 (12-04)

02/05/08

Approved for use through 7/31/2006. OMB 0651-0032
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PATENT APPLICATION FEE DETERMINATION RECORD Substitute for Form PTO-875	Application or Docket Number 12/026,480

APPLICATION AS FILED – PART I

FOR	(Column 1) NUMBER FILED	(Column 2) NUMBER EXTRA	SMALL ENTITY RATE ($)	SMALL ENTITY FEE ($)	OR	OTHER THAN SMALL ENTITY RATE ($)	OTHER THAN SMALL ENTITY FEE ($)
BASIC FEE (37 CFR 1.16(a), (b), or (c))	N/A	N/A	N/A			N/A	310
SEARCH FEE (37 CFR 1.16(k), (i), or (m))	N/A	N/A	N/A			N/A	510
EXAMINATION FEE (37 CFR 1.16(o), (p), or (q))	N/A	N/A	N/A			N/A	210
TOTAL CLAIMS (37 CFR 1.16(i))	57 minus 20 =	* 37	X 25=		OR	X 50=	1850
INDEPENDENT CLAIMS (37 CFR 1.16(h))	2 minus 3 =	*	X 105=			X 210=	
APPLICATION SIZE FEE (37 CFR 1.16(s))	If the specification and drawings exceed 100 sheets of paper, the application size fee due is $250 ($125 for small entity) for each additional 50 sheets or fraction thereof. See 35 U.S.C. 41(a)(1)(G) and 37 CFR						
MULTIPLE DEPENDENT CLAIM PRESENT (37 CFR 1.16(j))			N/A			N/A	
* If the difference in column 1 is less than zero, enter "0" in column 2.			TOTAL			TOTAL	2880

APPLICATION AS AMENDED – PART II

AMENDMENT A		(Column 1) CLAIMS REMAINING AFTER AMENDMENT		(Column 2) HIGHEST NUMBER PREVIOUSLY PAID FOR	(Column 3) PRESENT EXTRA	SMALL ENTITY RATE ($)	SMALL ENTITY ADDI-TIONAL FEE ($)	OR	OTHER THAN SMALL ENTITY RATE ($)	OTHER THAN SMALL ENTITY ADDI-TIONAL FEE ($)
	Total (37 CFR 1.16(i))	*	Minus	**	=	x =		OR	x =	
	Independent (37 CFR 1.16(h))	*	Minus	***	=	x =		OR	x =	
	Application Size Fee (37 CFR 1.16(s))									
	FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))					N/A		OR	N/A	
						TOTAL ADD'T FEE		OR	TOTAL ADD'T FEE	

AMENDMENT B		(Column 1) CLAIMS REMAINING AFTER AMENDMENT		(Column 2) HIGHEST NUMBER PREVIOUSLY PAID FOR	(Column 3) PRESENT EXTRA	RATE ($)	ADDI-TIONAL FEE ($)	OR	RATE ($)	ADDI-TIONAL FEE ($)
	Total (37 CFR 1.16(i))	*	Minus	**	=	x =		OR	x =	
	Independent (37 CFR 1.16(h))	*	Minus	***	=	x =		OR	x =	
	Application Size Fee (37 CFR 1.16(s))									
	FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))					N/A		OR	N/A	
						TOTAL ADD'T FEE		OR	TOTAL ADD'T FEE	

* If the entry in column 1 is less than the entry in column 2, write "0" in column 3.
** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 20, enter "20".
*** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 3, enter "3".
The "Highest Number Previously Paid For" (Total or Independent) is the highest number found in the appropriate box in column 1.

This collection of information is required by 37 CFR 1.16. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 12 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

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