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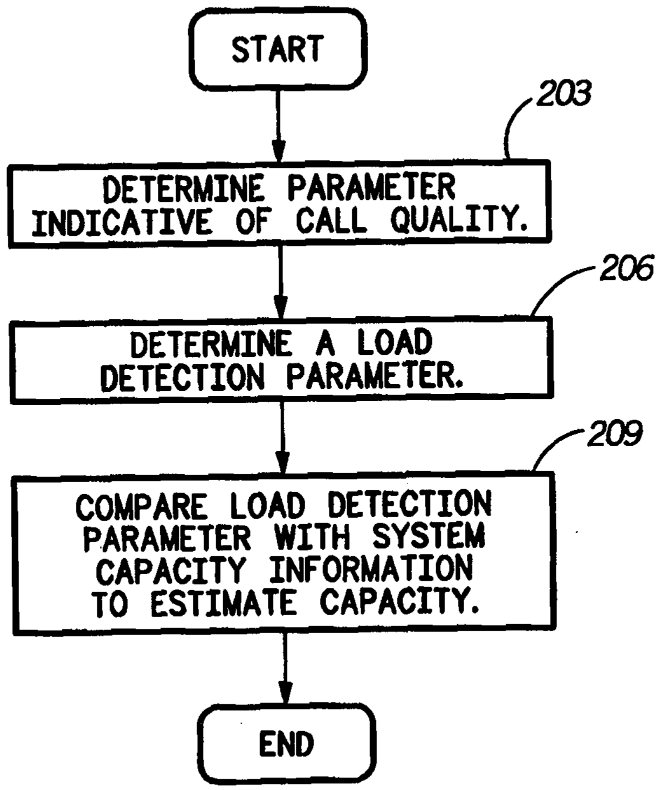
(57) Abstract

A communication system (100) implements improved capacity estimation. The system (100) determines a call quality parameter (203) related to communication resources in use within the communication system (100), then determines a load detection parameter (206) which provides information regarding the amount of time a normalized call quality parameter was above a link threshold. To estimate system capacity, the system (100) compares (209) the load detection parameter with information related to system capacity to characterize the system (100) and estimate the capacity of the system (100).



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METHOD AND APPARATUS FOR ESTIMATING CAPACITY IN A COMMUNICATION SYSTEM

FIELD OF THE INVENTION

The present invention relates generally to communication systems and, more particularly, to determining capacity overload in such communication systems.

BACKGROUND OF THE INVENTION

In communication systems, for example cellular radiotelephone systems, system planning capability is critical to proper operation of an installed system. For example, operators of such cellular radiotelephone systems need a way to forecast, inter alia, radio frequency (RF) capacity needs and equipment needs so that they can plan well in advance the introduction of capacity enhancing features such as new cell sites, sectorization of existing omni sites, micro-cells and additional RF carriers. The difficulty in providing useful tools to the operators to make this forecast lies inherently in the difficulty of characterizing the existing cellular radiotelephone system for parameters such as voice quality of a user versus the impact all users have on the capacity of the system.

Thus, a need exists for a method and apparatus which improves the characterization of existing cellular radiotelephone systems.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 generally depicts a block diagram of a communication system which may beneficially implement the noise suppression system in accordance with the invention.

FIG. 2 generally depicts the steps performed in the preferred embodiment to determine capacity overload in accordance with the invention.

FIG. 3 generally depicts how the parameter indicative of call quality is determined in accordance with the invention.

FIG. 4 generally depicts how the load detection parameter is determined in accordance with the invention.

FIG. 5 generally depicts how the load detection parameter is implemented in accordance with the invention.

FIG. 6 generally depicts the normalized forward link call quality parameter (NFLCQP) versus frame error rate (FER) characterization in accordance with the invention.

FIG. 7 generally depicts the normalized reverse link call quality parameter (NRLCQP) versus frame error rate (FER) characterization in accordance with the invention.

FIG. 8 generally depicts the load detection parameter versus the usage of Erlangs in accordance with the invention.

DETAILED DESCRIPTION OF A PREFERRED EMBODIMENT

Stated generally, a communication system implements improved capacity estimation. The system determines a call quality parameter related to communication resources in use within the communication system, then determines a load detection parameter which provides information regarding the amount of time a normalized call quality parameter was above a link threshold. To estimate system capacity, the system compares the load detection parameter with information related to system capacity to characterize the system and estimate the capacity of the system.

In the preferred embodiment, the communication system is a code-division multiple access (CDMA) communication system. Also in the preferred embodiment, the load detection parameter is related to a frame error rate parameter correlated to the coverage area, and more specifically is the frame error rate parameter correlated to the coverage area normalized by the time the communication resource is in use. The load detection parameter is determined for both a reverse link and a forward link of the communication resource to produce a corresponding reverse link detection parameter and a forward link detection parameter. The load detection parameter includes information related to a time in which the load detection parameter is above a predetermined threshold during an observation time period, which is itself variable. The parameter indicative of call quality for a plurality of the communication resources is determined over a predetermined period of time.

FIG. 1 generally depicts a block diagram of a communication system 100 which may beneficially implement the techniques described herein related to capacity overload determination in accordance with the invention. In the preferred embodiment, the communication system is a code division multiple access (CDMA) cellular radiotelephone system. As one of ordinary skill in the art will appreciate, however, the techniques described herein in accordance with the invention can be implemented in any communication system which would benefit from the system. Such systems include, but are not limited to, voice mail systems, cellular radiotelephone systems, trunked communication systems, airline communication systems, etc.

Referring to FIG. 1, acronyms are used for convenience. The following is a list of definitions for the acronyms used in FIG. 1:

BTS	Base Transceiver Station
CBSC	Centralized Base Station Controller
VLR	Visitor Location Register
HLR	Home Location Register
MS	Mobile Station

MSC	Mobile Switching Center
MM	Mobility Manager
OMCR	Operations and Maintenance Center - Radio
OMCS	Operations and Maintenance Center - Switch
PSTN	Public Switched Telephone Network
TC	Transcoder

As seen in FIG. 1, a BTS 101-103 is coupled to a CBSC 104. Each BTS 101-103 provides radio frequency (RF) communication to an MS 105. In the preferred embodiment, the transmitter/receiver (transceiver) hardware implemented in the BTSs 101-103 and the MSs 105 to support the RF communication is defined in the document titled TIA/EIA/IS-95A, *Mobile Station-Base Station Compatibility Standard for Dual Mode Wideband Spread Spectrum Cellular System,* March 1995 available from the Telecommunication Industry Association (TIA). The CBSC 104 is responsible for, inter alia, call processing and mobility management via the MM 109. Other tasks of the CBSC 104 include feature control and transmission/networking interfacing. For more information on the functionality of the CBSC 104, reference is made to United States Patent No. 5,475,686 to Bach et al., assigned to the assignee of the present application, and incorporated herein by reference.

Also depicted in FIG. 1 is an OMCR 112 coupled to the MM 109 of the CBSC 104. The OMCR 112 is responsible for the operations and general maintenance of the radio portion (CBSC 104 and BTS 101-103 combination) of the communication system 100. The CBSC 104 is coupled to an MSC 115 which provides switching capability between the PSTN 120 and the CBSC 104. The OMCS 124 is responsible for the operations and general maintenance of the switching portion (MSC 115) of the communication system 100. The HLR 116 and VLR 117 provide the communication system 100 with user information primarily used for billing purposes. The functionality of the CBSC 104, MSC 115, HLR 116 and VLR 117 is shown in FIG. 1 as distributed, however one of ordinary skill in the art will appreciate that the functionality could likewise be centralized into a single element.

In the preferred embodiment, the CBSC 104 performs signal compression as is well known in the art. The link 126 coupling the MSC 115 with the CBSC 104 is a T1/E1 link which is also well known in the art. The compressed signal is transferred to a particular BTS 101-103 for transmission to the MS 105. Important to note is that the compressed signal transferred to a particular BTS 101-103 undergoes further processing at the BTS 101-103 before transmission occurs. Put differently, the eventual signal transmitted to the MS 105 is different in form but the same in substance as the compressed signal exiting the CBSC 104.

When the MS 105 receives the signal transmitted by a BTS 101-103, the MS 105 will essentially "undo" (commonly referred to as "decode") all of the processing done at the BTS 101-103 and the compression performed by the CBSC 104. When the MS 105 transmits a signal back to a BTS 101-103, the MS 105 likewise implements compression. After a signal having undergone compression is transmitted by the MS 105 (the MS also performs further processing of the signal to change the form, but not the substance, of the signal) to a BTS 101-103, the BTS 101-103 will "undo" the processing performed on the signal and transfer the resulting signal to the CBSC 104 for speech decoding. After speech decoding by the CBSC 104, the signal is transferred to an end user via the T1/E1 link 126.

FIG. 2 generally depicts the steps performed in the preferred embodiment to determine capacity overload in accordance with the invention. In the preferred embodiment, the process of FIG. 2 is performed in the OMCR 112, however one skilled in the art will realize that the process could equally be performed at the CBSC 104 or even the BTS 101-103. As seen in FIG. 2, a parameter indicative of call quality is determined at step 203 and the corresponding call quality parameter produced at step 203 is correlated to a particular coverage area to produce a load detection parameter at step 206. To determine capacity overload in accordance with the invention, the load detection parameter is compared with system capacity information at step 209 and, based on the comparison, an estimate of capacity of the communication system is determined. Each of the steps 203, 206 and 209 are explained in greater detail below.

FIG. 3 generally depicts how the parameter indicative of call quality is determined in accordance with the invention. To begin, a test is performed at 303 to determine whether the parameter is related to the forward link or the reverse link of the communication resource. As one of ordinary skill in the art will appreciate, the communication resource is a full duplex communication resource, meaning that the forward link and the reverse link are separated by one another in frequency. Referring back to FIG. 3, if the test at step 303 yields that the parameter is for the forward link, the parameter is so determined when three power measurement report messages (PMRM) are received by a base-station within a ten second window as shown at step 306. If, however, the test at step 303 yields that the parameter is for the reverse link, the parameter is determined when 14 frame errors occur within a span of 128 frames as shown at step 309. For this particular step, the value of 14 frame errors out of a span of 128 frames is calibrated to yield a frame error rate (FER) of approximately 1%. In either event, the parameter indicative of call quality exiting steps 306 and/or 309 are input into step 206. While the specific parameters for determining the call quality parameter have been listed in steps 306 and 309 in accordance with the preferred embodiment, one of ordinary skill in the art will appreciate that any number of different parameters could be utilized depending on the parameters readily available in the particular communication system.

FIG. 4 generally depicts how the load detection parameter is produced in accordance with the invention. In the preferred embodiment, the load detection parameter is computed each time a communication resource (i.e., a call) is released. As one of ordinary skilled in the art will appreciate, the load detection parameter could be computed periodically as well. As shown in FIG. 4, the call quality parameter obtained from step 203 is, in effect, assigned to a particular coverage area within the communication system at step 403. In the preferred embodiment, the assignment is based on the last cell/sector that the MS 105-106 was in. Next, at step 406, the release time within a window of a minute of the MS 105-106 is recorded. The call quality parameters for each communication within the coverage area are next summed at step 409, and the sum is then normalized at step 412 by the sum of the times the particular communication resources were in use during the minute window to determine a load detection parameter. The load detection parameter is a measure, in seconds, of how long the load detection parameter was above a predetermined threshold during an observation period as shown in FIG. 8. In the preferred embodiment the observation period is variable and can range anywhere from one minute to a full day. Referring back to FIG. 4, the load detection parameter is incremented at step 415 if the parameter is above a link threshold. In the preferred embodiment, the threshold is 1 for the forward link and 4 for the reverse link. Important to note is that the normalized call quality parameters are both a normalized forward link call quality parameter (NFLCQP) and a normalized reverse link call quality parameter (NRLCQP) .

The NFLCQP and the NRLCQP have the property that they can be accurately correlated to FERs within the communication system. For example, as shown in FIG. 6 and FIG. 7, the NFLCQP and NRLCQP (respectively) are shown to act like flags, moving very quickly from zero to their maximum value as the FER increases from less than 1% to 3%. This property of both the NFLCQP and the NRLCQP makes them early indicators of impending poor voice quality which, as described with reference to the prior art, was previously difficult to detect. As such, the NFLCQP and the NRLCQP are used to characterize the cellular radiotelephone system for parameters such as voice quality of a user versus the impact all users have on the capacity of the system in accordance with the invention.

FIG. 5 generally depicts how the load detection parameter is implemented in accordance with the invention. As shown in FIG. 5, information regarding the cell/sector capacity is next gathered at step 503. In the preferred embodiment, the information regarding cell/sector capacity is the number of Erlangs used in the particular cell/sector during the observation period. At step 506, the load detection parameter is compared with the information related to the cell/sector capacity and a correlation between the two is computed. In the preferred embodiment, the correlation is performed using well known linear regression techniques, the result of which is shown in FIG. 8 where the load detection parameter is compared versus the usage of Erlangs. The threshold 803 is chosen to be 10% of the total number of seconds that the load detection parameter could be above the link threshold for an observation period of one hour. The total number of seconds is the total minutes in the observation period (i.e., one hour = 3600 seconds).

At this point, a test is performed at step 509 to determine if the correlation is greater than a predetermined correlation. In the preferred embodiment, a correlation of .6 or better is used to infer that the high number of events is due to the number of users (i.e., capacity) of the communication system, but any correlation suitable to the situation may be used. If the result of the test at step 509 is negative, then the coverage area is not capacity-limited and is thus experiencing problems due to something other than the total number of users on the system. Some typical "other" problems that the coverage area may be experiencing can be interference presented by mobile stations within the coverage area, interference presented by other mobile stations outside of the coverage area, poor radio frequency (RF) received signal strength indications (RSSIs) from desired mobiles within the coverage area, etc.

If, however, the test at step 509 is positive, then another test is performed at step 515 to determine if the load detection parameter is greater than a predetermined threshold 803. If the result of this test is negative, then the coverage area is capacity limited but not fully loaded. As such, the process flows to step 518 where the percentage of system loading is computed and the maximum capacity is then forecasted. The maximum capacity is forecasted by determining the number of Erlangs in use when the linear regression 806 crosses the predetermined threshold 803. As shown in FIG. 8, this value would be approximately 16 Erlangs. If the result of the test at step 515 is positive, the coverage area capacity-limited and is deemed to be at full capacity at step 521. Thus, by undergoing the process in accordance with the invention, the communication system can be characterized with respect to system loading. For long observation periods (for example, one hour or greater), the method described herein is primarily beneficial to indicate to an operator that the coverage area is experiencing problems on either the forward link or the reverse link, and the problem is correlated with system load. As potential solutions to the problem, an operator might perform coverage area splitting, pilot signal power adjustment, addition of an extra RF channel, etc. to alleviate the problem.

If the observation period is shortened (say to five minutes) then near (real-time) information regarding the loading of the system is provided in accordance with the invention. In this situation, after a five minute observation period, the communication system can be arranged to block incoming calls if the condition at step 521 occurs. Stated differently, if capacity overload is determined at step 521 in accordance with the invention, the coverage area is at full capacity and cannot sustain or support communications with any more mobile stations which desire a communication resource. As such, the CBSC 104 or the BTS 101-103 can be arranged to disallow (commonly referred to in the art as "block") any new MSs which request access to a communication resource within the particular coverage area which is at full capacity as determined at step 521. In this manner, the techniques described in accordance with the invention are not merely an overload detection mechanism but is an overload control mechanism in accordance with the invention.

While the invention has been particularly shown and described with reference to a particular embodiment, it will be understood by those skilled in the art that various changes in form and details may be made therein without departing from the spirit and scope of the invention. The corresponding structures, materials, acts and equivalents of all means or step plus function elements in the claims below are intended to include any structure, material, or acts for performing the functions in combination with other claimed elements as specifically claimed.

What is claimed is:

Claims

1. A method of estimating capacity in a communication system, the communication system including a base-station responsive to a mobile station via a communication resource, the method comprising the steps of:

determining a call quality parameter indicative of call quality for a plurality of the communication resources;

determining, using the call quality parameter, a load detection parameter related to the amount of usage of communication resources in a coverage area; and

comparing the load detection parameter to system capacity information for the coverage area to estimate capacity of the communication system.

2. The method of claim 1, wherein the load detection parameter is related to a frame error rate parameter correlated to the coverage area.

3. The method of claim 2, wherein the load detection parameter further comprises the frame error rate parameter correlated to the coverage area normalized by the time the communication resource is in use.

4. The method of claim 3, wherein the load detection parameter is determined for both a reverse link and a forward link of the communication resource to produce a corresponding reverse link detection parameter and a forward link detection parameter.

5. The method of claim 1, wherein the load detection parameter includes information related to a time in which the load detection parameter is above a predetermined threshold during an observation time period.

6. An apparatus for estimating capacity in a communication system, the communication system including a base-station responsive to a mobile station via a communication resource, the apparatus comprising:

means for determining a call quality parameter indicative of call quality for a plurality of the communication resources;

means, coupled to the means for determining a call quality parameter, for determining a load detection parameter related to the amount of usage of communication resources in a coverage area; and

means for comparing the load detection parameter to system capacity information for the coverage area to estimate capacity of the communication system.

7. The apparatus of claim 6, wherein the load detection parameter is related to a frame error rate parameter correlated to the coverage area.

8. The apparatus of claim 7, wherein the load detection parameter further comprises the frame error rate parameter correlated to the coverage area normalized by the time the communication resource is in use.

9. The apparatus of claim 8, wherein the load detection parameter is determined for both a reverse link and a forward link of the communication resource to produce a corresponding reverse link detection parameter and a forward link detection parameter.

10. A method of estimating capacity in a communication system, the communication system including a base-station responsive to a mobile station via a communication resource, the method comprising the steps of:

determining a call quality parameter indicative of call quality for either a forward or reverse link of a plurality of the communication resources;

determining, using the call quality parameter, a load detection parameter related to the amount of usage of communication resources in a coverage area; and

comparing the load detection parameter to Erlang usage for the coverage area to estimate capacity of the communication system.

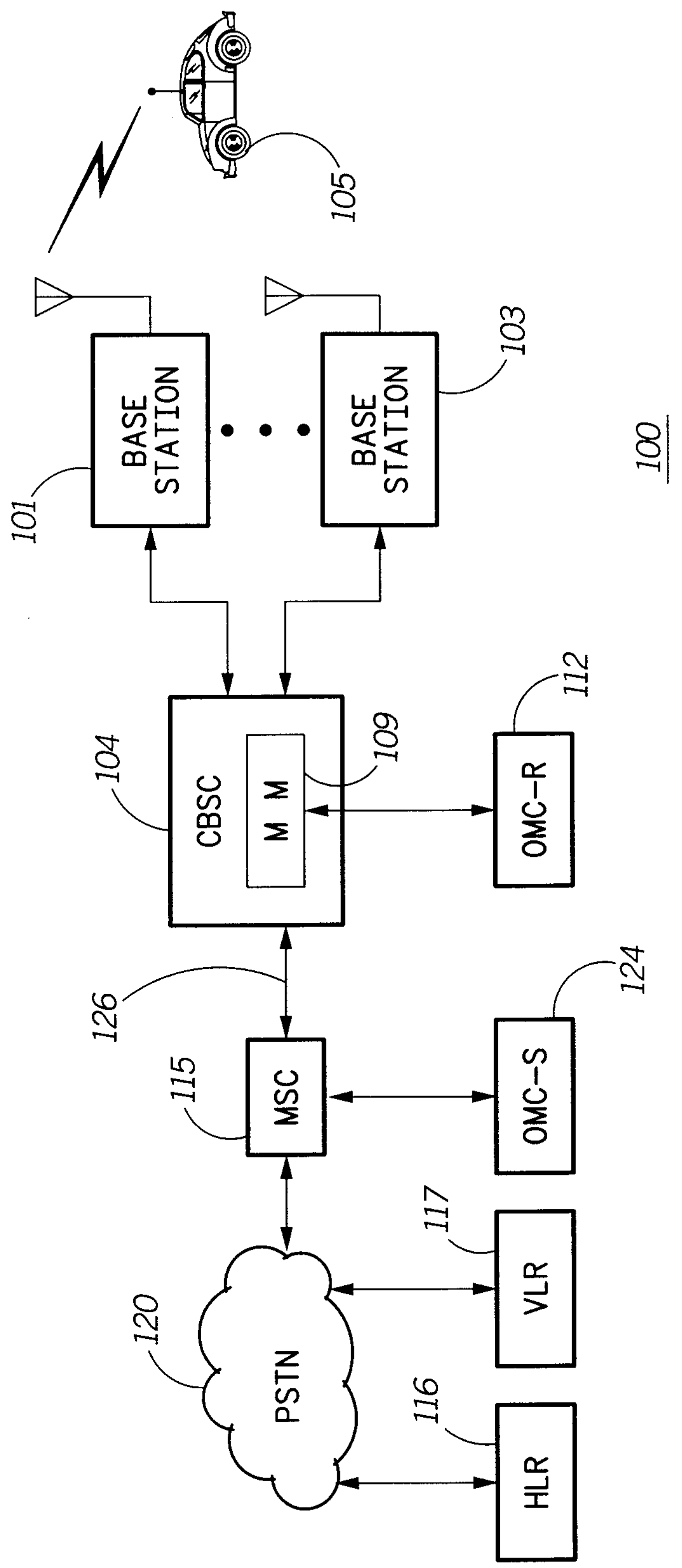
105
101
BASE STATION
BASE STATION
103
100
104
CBSC
M M
109
OMC-R
112
126
115
MSC
OMC-S
124
120
PSTN
117
VLR
116
HLR

FIG. 1

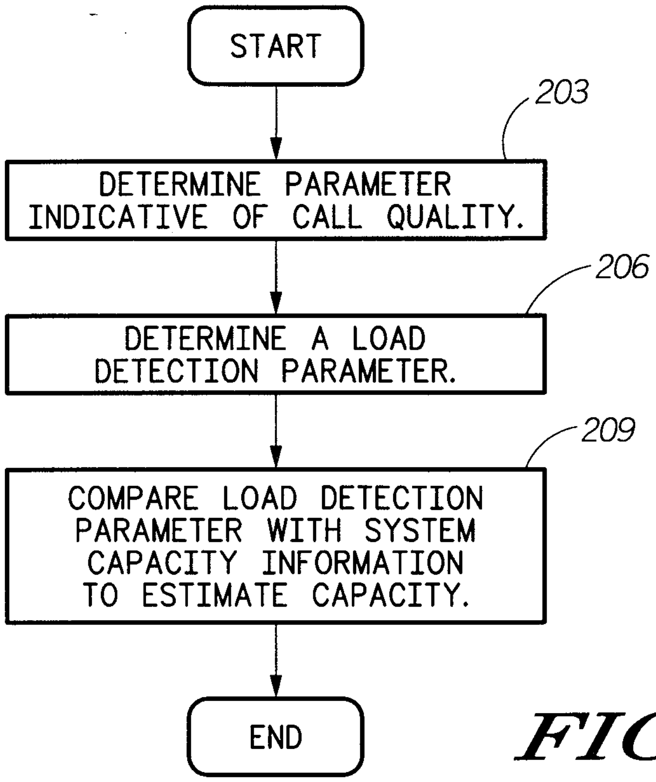
START
203
DETERMINE PARAMETER INDICATIVE OF CALL QUALITY.
206
DETERMINE A LOAD DETECTION PARAMETER.
209
COMPARE LOAD DETECTION PARAMETER WITH SYSTEM CAPACITY INFORMATION TO ESTIMATE CAPACITY.
END

FIG. 2

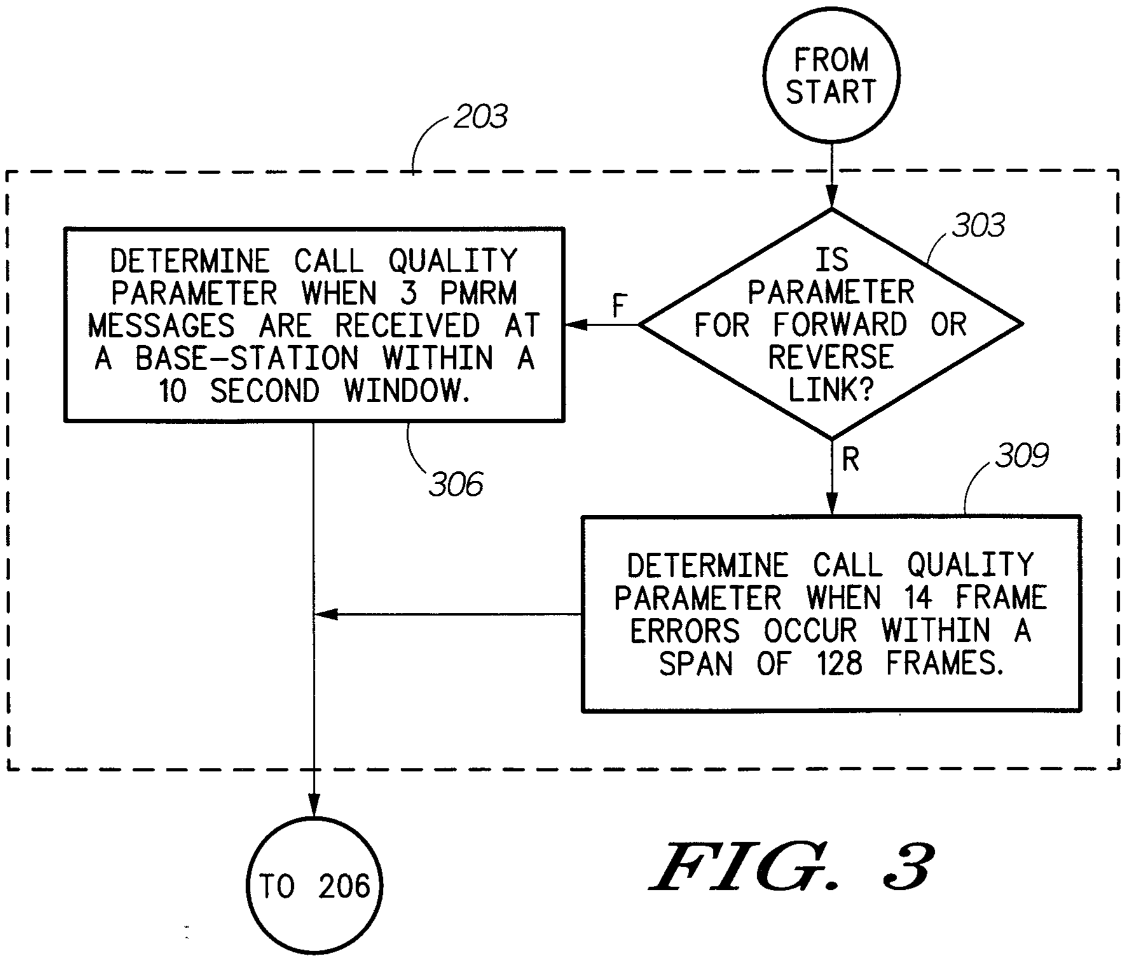
FROM START
203
IS PARAMETER FOR FORWARD OR REVERSE LINK?
303
F
DETERMINE CALL QUALITY PARAMETER WHEN 3 PMRM MESSAGES ARE RECEIVED AT A BASE-STATION WITHIN A 10 SECOND WINDOW.
306
R
309
DETERMINE CALL QUALITY PARAMETER WHEN 14 FRAME ERRORS OCCUR WITHIN A SPAN OF 128 FRAMES.
TO 206

FIG. 3

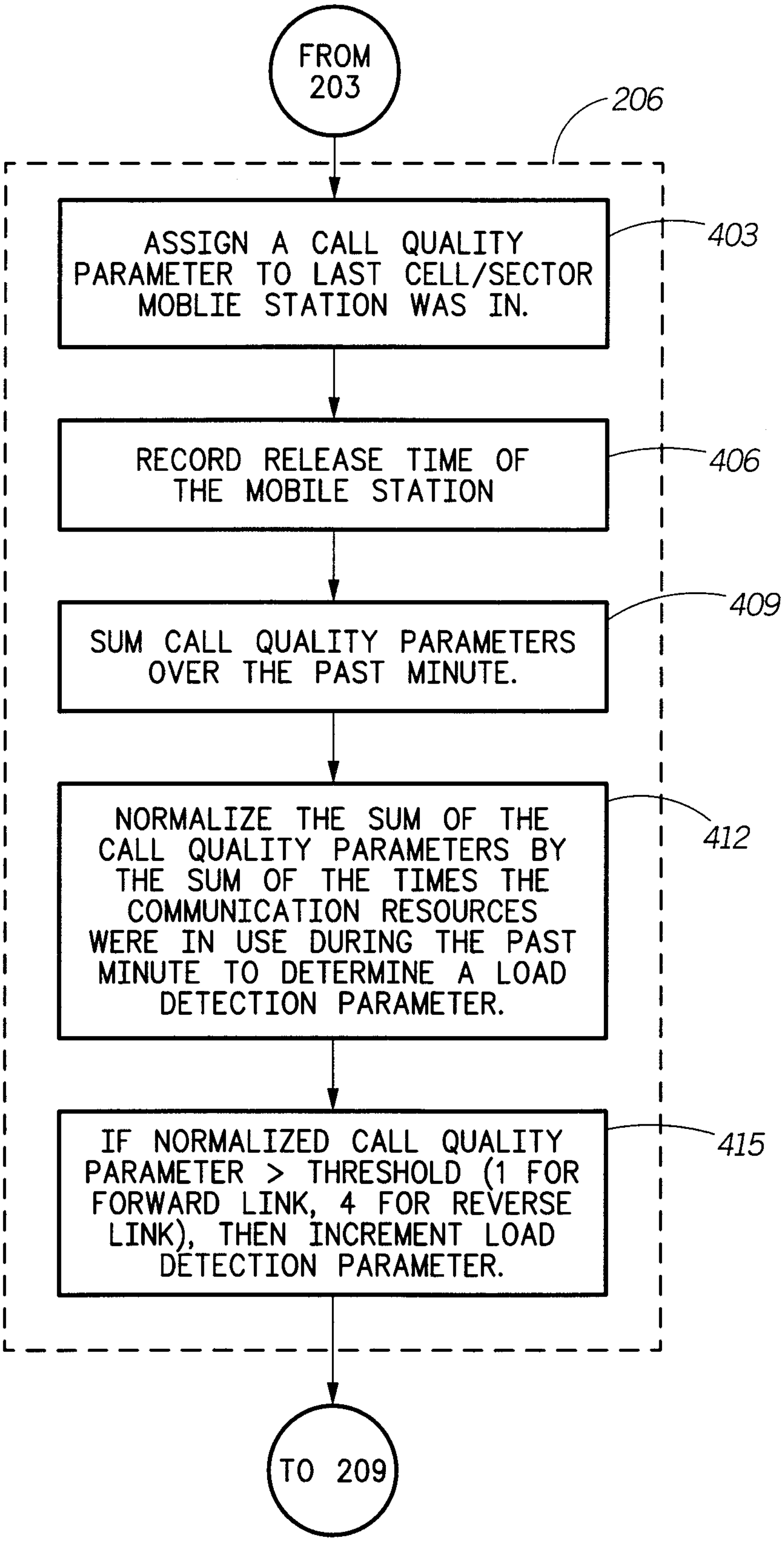
FROM 203
206
ASSIGN A CALL QUALITY PARAMETER TO LAST CELL/SECTOR MOBLIE STATION WAS IN.
403
RECORD RELEASE TIME OF THE MOBILE STATION
406
SUM CALL QUALITY PARAMETERS OVER THE PAST MINUTE.
409
NORMALIZE THE SUM OF THE CALL QUALITY PARAMETERS BY THE SUM OF THE TIMES THE COMMUNICATION RESOURCES WERE IN USE DURING THE PAST MINUTE TO DETERMINE A LOAD DETECTION PARAMETER.
412
IF NORMALIZED CALL QUALITY PARAMETER > THRESHOLD (1 FOR FORWARD LINK, 4 FOR REVERSE LINK), THEN INCREMENT LOAD DETECTION PARAMETER.
415
TO 209

FIG. 4

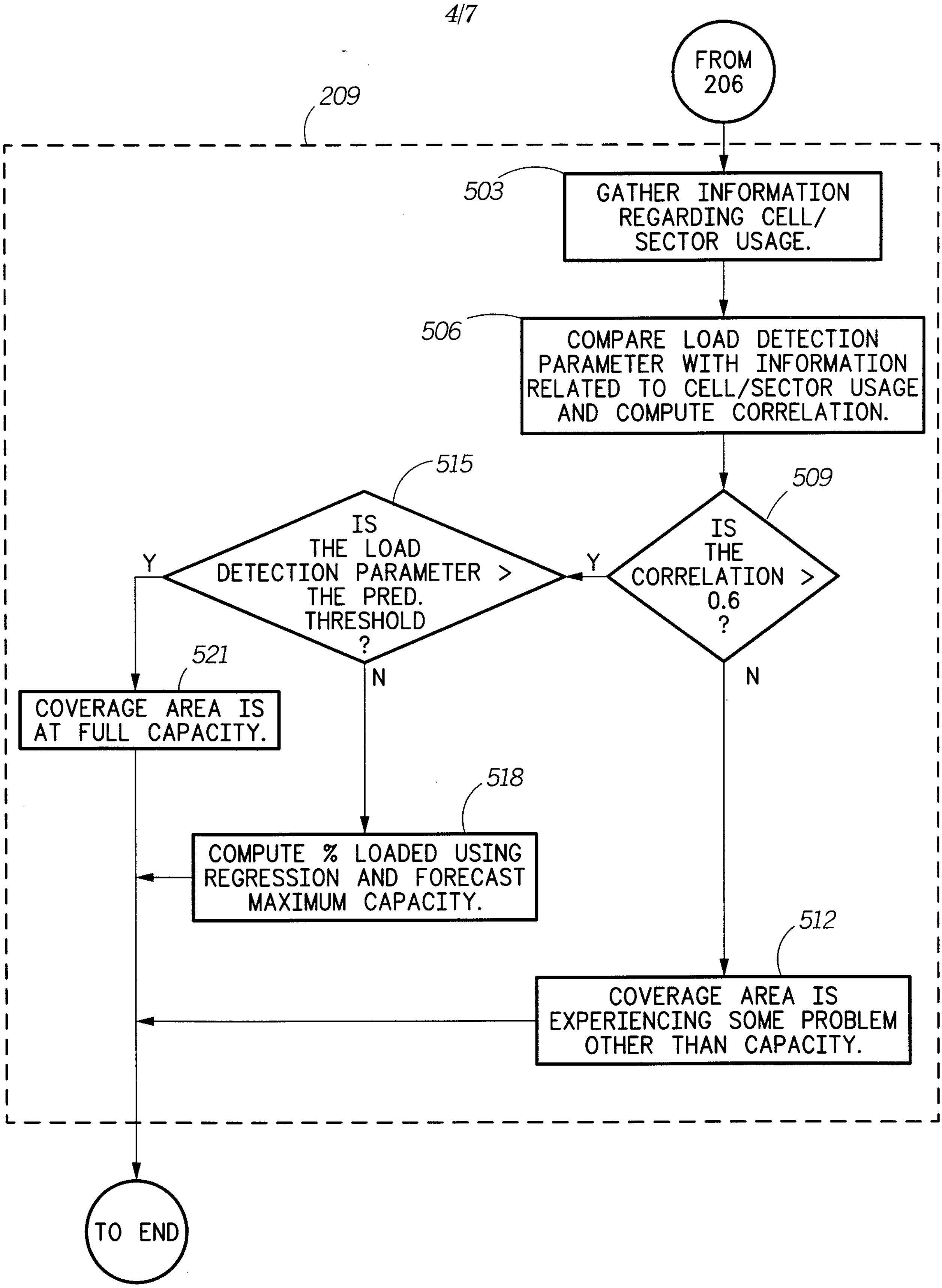
FROM 206
209
503
GATHER INFORMATION REGARDING CELL/ SECTOR USAGE.
506
COMPARE LOAD DETECTION PARAMETER WITH INFORMATION RELATED TO CELL/SECTOR USAGE AND COMPUTE CORRELATION.
515
509
IS THE LOAD DETECTION PARAMETER > THE PRED. THRESHOLD ?
Y
Y
IS THE CORRELATION > 0.6 ?
521
N
N
COVERAGE AREA IS AT FULL CAPACITY.
518
COMPUTE % LOADED USING REGRESSION AND FORECAST MAXIMUM CAPACITY.
512
COVERAGE AREA IS EXPERIENCING SOME PROBLEM OTHER THAN CAPACITY.
TO END

FIG. 5

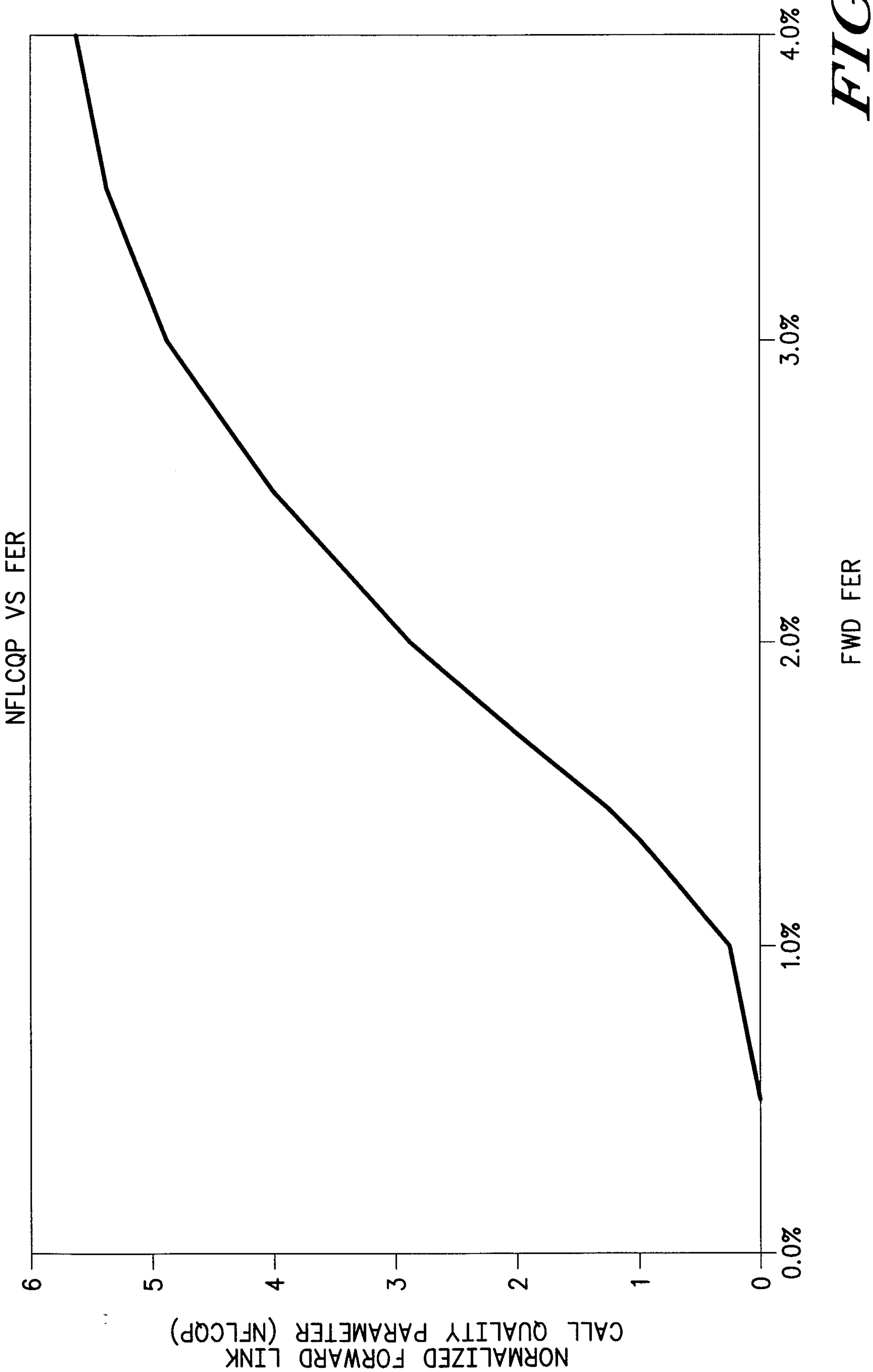
NFLCQP VS FER
NORMALIZED FORWARD LINK
CALL QUALITY PARAMETER (NFLCQP)
0
1
2
3
4
5
6
FWD FER
0.0%
1.0%
2.0%
3.0%
4.0%

FIG. 6

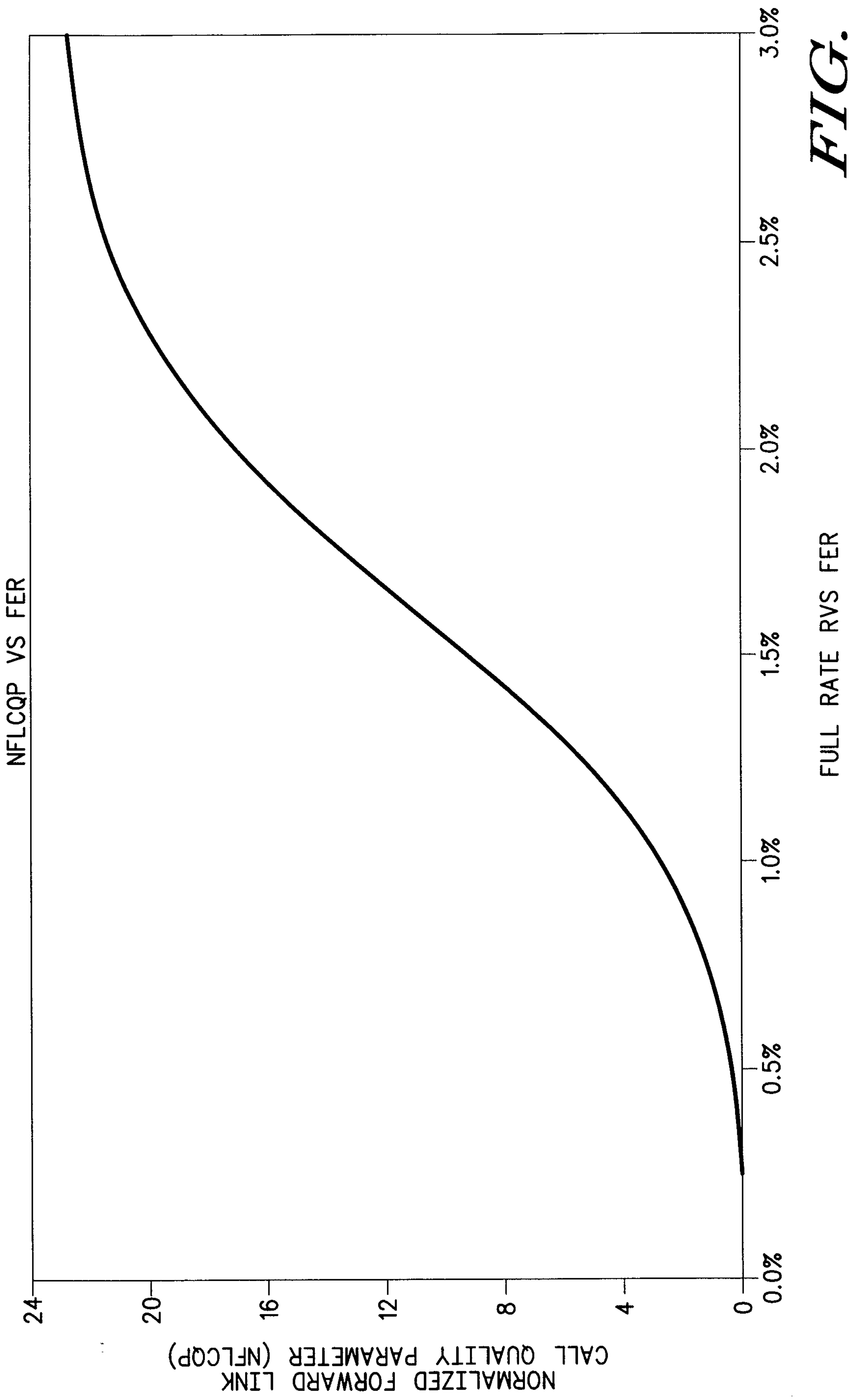
NFLCQP VS FER
NORMALIZED FORWARD LINK CALL QUALITY PARAMETER (NFLCQP)
0
4
8
12
16
20
24
0.0%
0.5%
1.0%
1.5%
2.0%
2.5%
3.0%
FULL RATE RVS FER

FIG. 7

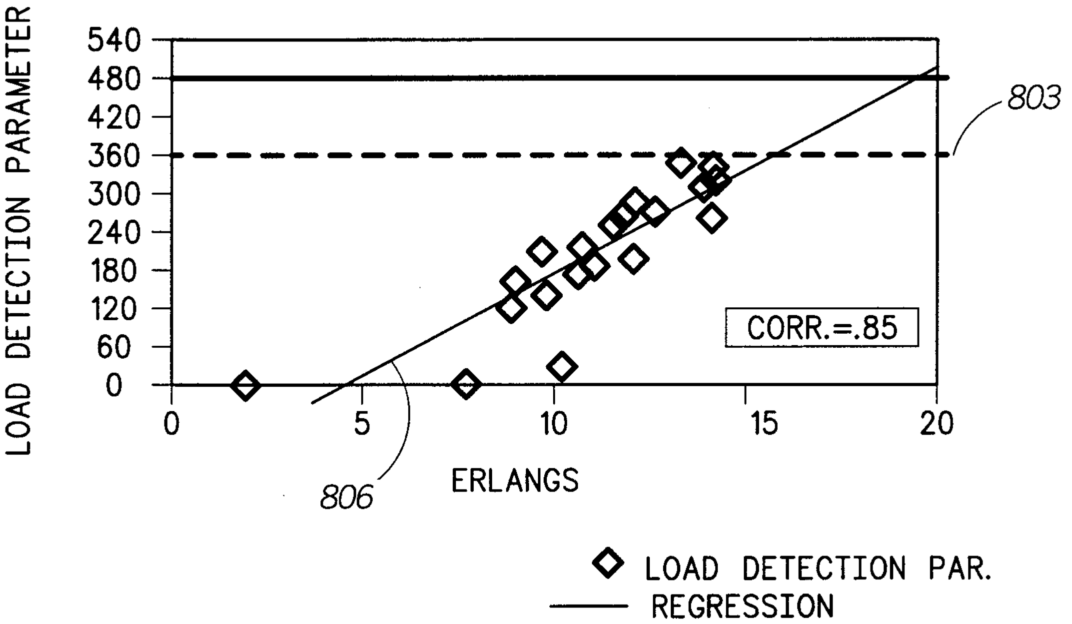
LOAD DETECTION PARAMETER
540
480
420
360
300
240
180
120
60
0
0
5
10
15
20
ERLANGS
CORR.=.85
803
806
LOAD DETECTION PAR.
REGRESSION

FIG. 8

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US98/02136

A. CLASSIFICATION OF SUBJECT MATTER

IPC(6) :H04B 1/00, 15/00; H04Q 7/20, 7/30, 7/36
US CL :Please See Extra Sheet.
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. : 370/200, 252, 241, 329, 332, 333; 455/422, 436, 439, 446, 453, 454, 501

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)

APS

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 4,670,899 A (BRODY ET AL) 02 June 1987, Abstract, claim 8, Fig. 7-8, col. 7-8	1, 2, 6, 10
A	US 5,239,640 A (FROEMKE ET AL.) 24 August 1993	1, 6, 10
A	US 5,448,621 A (KNUDSEN) 05 September 1995	1
A	US 5,448,754 A (HO ET AL) 05 September 1995	1, 6

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

* Special categories of cited documents:

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/US98/02136

A. CLASSIFICATION OF SUBJECT MATTER:
US CL :

370/200, 252, 241, 329, 332, 333; 455/422, 436, 439, 446, 453, 454, 501