United States Patent [19]

Raleigh et al.

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[54] **ADAPTIVE BEAM FORMING FOR TRANSMITTER OPERATION IN A WIRELESS COMMUNICATION SYSTEM**

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[73] Assignees: **The Board of Trustees of the Leland Stanford Jr. University**, Stanford; **Cisco Technology, Inc.**, San Jose, both of Calif.

[*] Notice: This patent issued on a continued prosecution application filed under 37 CFR 1.53(d), and is subject to the twenty year patent term provisions of 35 U.S.C. 154(a)(2).

[21] Appl. No.: **08/491,044**

[22] Filed: **Jun. 16, 1995**

Related U.S. Application Data

[63] Continuation-in-part of application No. 08/394,652, Feb. 22, 1995.

[51] **Int. Cl.**[7] **H04Q 7/30**
[52] **U.S. Cl.** **455/561**; 455/456; 455/65; 455/276.1; 342/367; 375/232
[58] **Field of Search** 455/33.1, 54.2, 54.1, 56.1, 63, 65, 67.1, 4, 115, 52.3, 226.1, 276.1, 272, 422, 440, 441, 456, 457, 517, 524, 525, 561, 562; 379/58, 59; 342/350, 367, 368, 372, 373, 378; 395/51; 375/316, 347, 349, 231, 230, 232
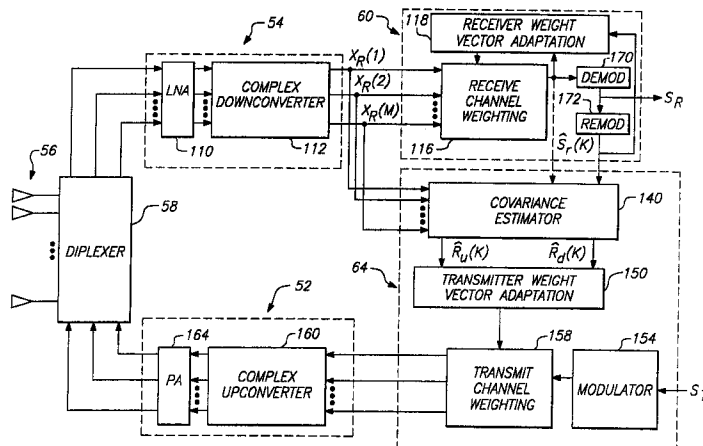
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Attorney, Agent, or Firm—Ritter Van Pelt & Yi LLP

[57] **ABSTRACT**

A method for forming an adaptive phased array transmission beam pattern at a base station without any knowledge of array geometry or mobile feedback is described. The approach is immune to the problems which plague methods which attempt to identify received angles of arrival from the mobile and map this information to an optimum transmit beam pattern. In addition, this approach does not suffer the capacity penalty and mobile handset complexity increase associated with mobile feedback. Estimates of the receive vector propagation channels are used to estimate transmit vector channel covariance matrices which form objectives and constraints in quadratic optimization problems leading to optimum beam former solutions for the single user case, and multiple user case. The new invention in capable of substantial frequency re-use capacity improvement in a multiple user cellular network.
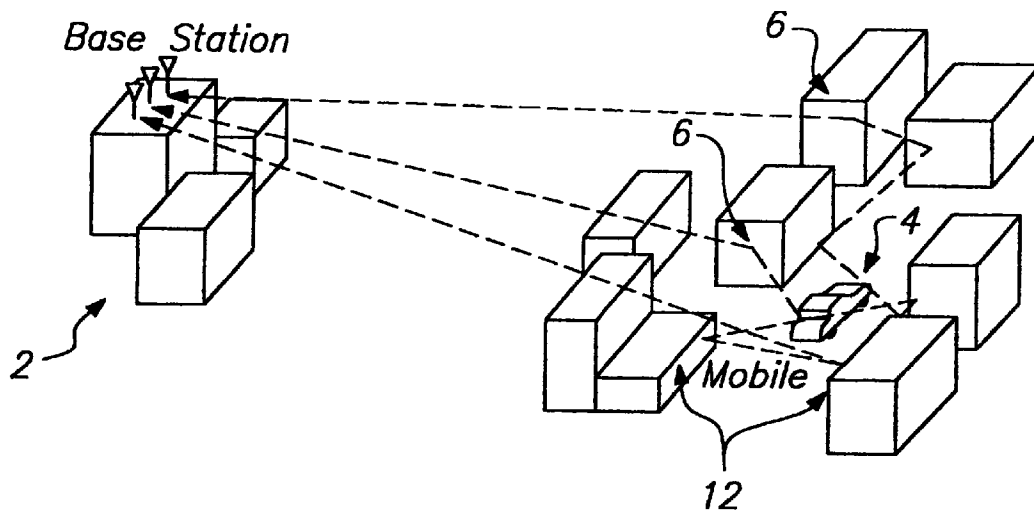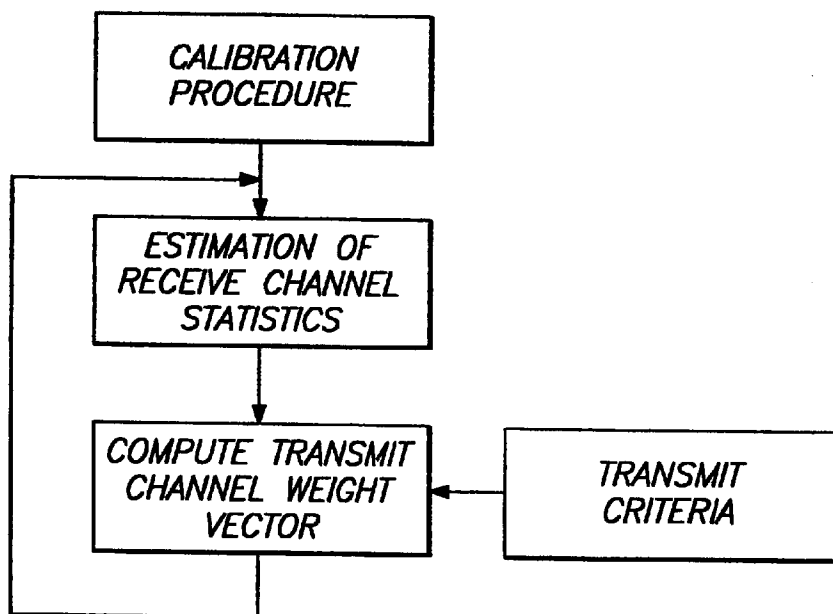
13 Claims, 11 Drawing Sheets

Base Station
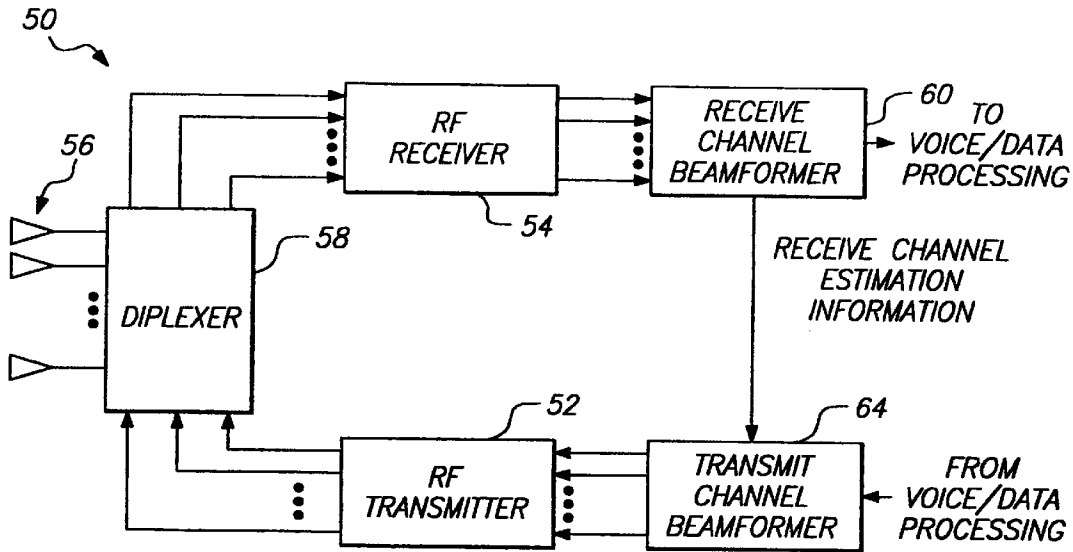
6

6

4

Mobile

2

12

FIG. 1

CALIBRATION
PROCEDURE

ESTIMATION OF
RECEIVE CHANNEL
STATISTICS

COMPUTE TRANSMIT
CHANNEL WEIGHT
VECTOR

TRANSMIT
CRITERIA

FIG. 4

FIG. 2A

FIG. 2B

FIG. 3

CALIBRATION
PROCEDURE

ESTIMATION OF
RECEIVE CHANNEL
STATISTICS

COMPUTE TRANSMIT
CHANNEL WEIGHT
VECTOR

TRANSMIT
CRITERIA

SATISFIED

NETWORK
AGREEMENT
CRITERIA

NOT
SATISFIED

DETERMINE NEW
CANDIDATE
FREQUENCY

NEW
FREQUENCY
AVAILABLE

NEW
FREQUENCY
UNAVAILABLE

SATISFIED

TRANSMISSION QUALITY
SATISFIES
PREDEFINED MINIMUM
CRITERIA

NOT
SATISFIED

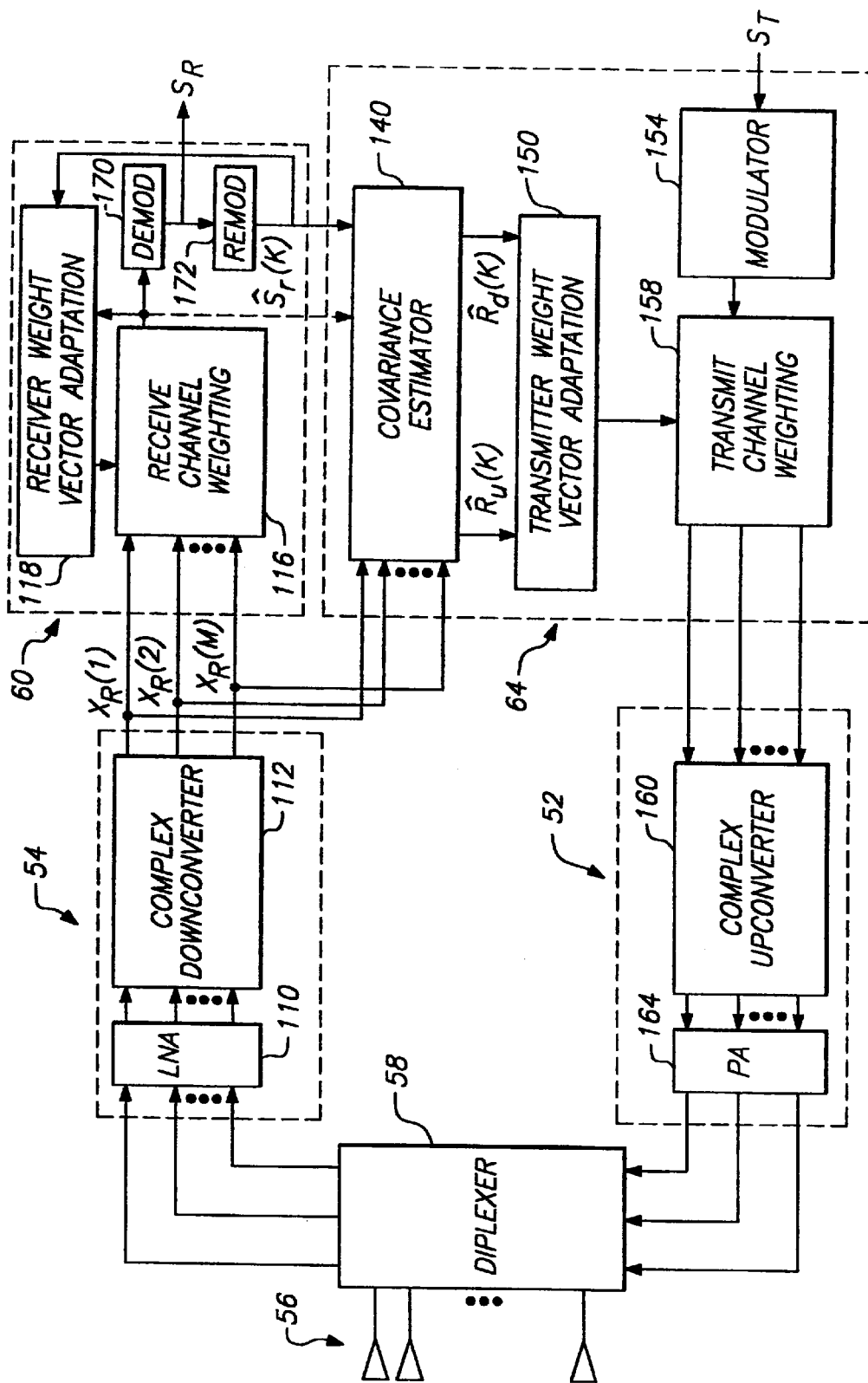TERMINATE CALL
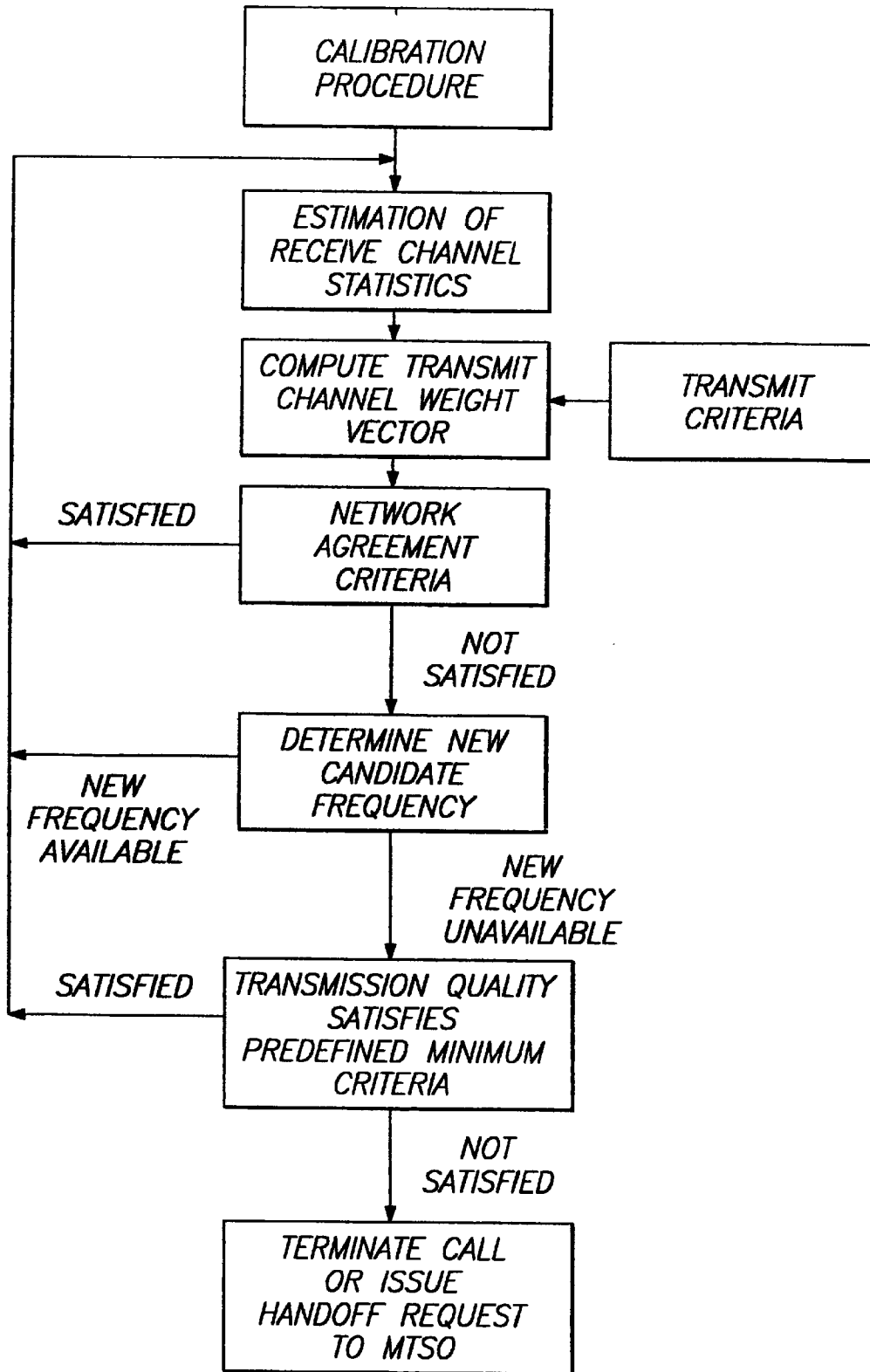OR ISSUE
HANDOFF REQUEST
TO MTSO

FIG. 5

DOCKET ALARM

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