US00RE39177E

(19) **United States**

(12) **Reissued Patent**

Padovani et al.

(10) **Patent Number: US RE39,177 E**

(45) **Date of Reissued Patent: Jul. 11, 2006**

(54) **METHOD AND APPARATUS FOR PERFORMING SOFT HAND-OFF IN A WIRELESS COMMUNICATION SYSTEM**

(75) Inventors: **Roberto Padovani**, San Diego, CA (US); **Roy Franklin Quick, Jr.**, San Diego, CA (US)

(73) Assignee: **Qualcomm, Inc.**, San Diego, CA (US)

(21) Appl. No.: **10/302,541**

(22) Filed: **Nov. 21, 2002**

Related U.S. Patent Documents

Reissue of:

(64) Patent No.: **6,151,502**
Issued: **Nov. 21, 2000**
Appl. No.: **08/790,497**
Filed: **Jan. 29, 1997**

(51) **Int. Cl.**
H04Q 7/20 (2006.01)

(52) **U.S. Cl.** **455/442**; 455/436; 455/525; 455/226.2; 370/331; 370/332

(58) **Field of Classification Search** 455/436, 455/437–444, 524, 525, 226.1–226.3, 137; 370/331, 332

See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

4,112,257	A	*	9/1978	Frost	179/2 EB
4,123,718	A	*	10/1978	Lampert et al.	325/474
4,765,753	A	*	8/1988	Schmidt	379/60
4,777,653	A	*	10/1988	Bonnerot et al.	455/69
4,811,421	A	*	3/1989	Havel et al.	455/69
4,868,795	A	*	9/1989	McDavid et al.	367/77
4,870,698	A	*	9/1989	Katsuyama et al.	455/67
4,901,307	A	*	2/1990	Gilhousen et al.	370/18
5,056,109	A	*	10/1991	Gilhousen et al.	375/1
5,093,840	A	*	3/1992	Schilling	375/1
5,101,501	A	*	3/1992	Gilhousen et al.	455/33
5,103,459	A	*	4/1992	Gilhousen et al.	375/1
5,107,487	A	*	4/1992	Vilmur et al.	370/18
5,128,965	A	*	7/1992	Henriksson	375/58
5,204,876	A	*	4/1993	Bruckert et al.	375/1
5,220,678	A	*	6/1993	Feei	455/69
5,245,629	A	*	9/1993	Hall	375/1
5,257,293	A	*	10/1993	Taguchi	370/1
5,265,119	A	*	11/1993	Gilhousen et al.	375/1
5,267,261	A	*	11/1993	Blakeney, II et al.	455/437
5,267,262	A	*	11/1993	Wheatley, III et al.	375/1
5,285,447	A	*	2/1994	Hulsebosch	455/437
5,305,468	A	*	4/1994	Bruckert et al.	455/69
5,383,219	A	*	1/1995	Wheatley, III et al.	375/1
5,390,338	A	*	2/1995	Bodin et al.	455/33.1
5,422,933	A	*	6/1995	Barnett et al.	379/60
5,450,616	A	*	9/1995	Rom	455/69
5,465,399	A	*	11/1995	Oberholtzer et al.	455/69
5,487,180	A	*	1/1996	Ohtake	455/54.1
5,539,744	A	*	7/1996	Chu et al.	455/436

(Continued)

FOREIGN PATENT DOCUMENTS

EP	615355	A2	*	9/1994
FR	2757734		*	6/1998
WO	9406218		*	3/1994
WO	9512297		*	5/1995

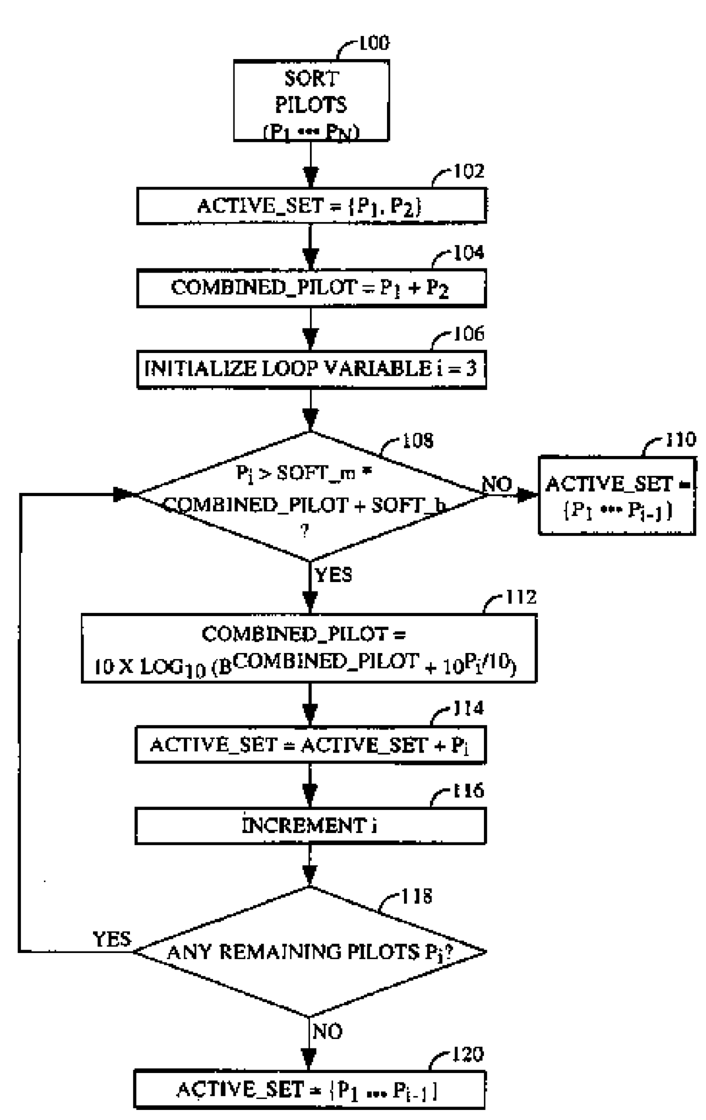
Primary Examiner—Duc M. Nguyen

(74) *Attorney, Agent, or Firm*—Philip Wadsworth; Sandra L. Godsey; Kyong H. Macek

(57) **ABSTRACT**

A method and apparatus for providing soft handoff in a mobile communication system. In current systems is that the members of active set are determined in accordance with comparisons of measured pilot energy with fixed thresholds. However, the value of providing a redundant communication link to a mobile station depends strongly on the energy of other signals being provided to the mobile station. In the present invention, the signal strengths of other base stations in communication with a mobile station are considered when determining whether adding a base to that set of base stations in communication with the remote station is of sufficient value to justify the impact on system capacity.

94 Claims, 8 Drawing Sheets



U.S. PATENT DOCUMENTS

5,577,022	A	*	11/1996	Padovani et al.	370/13
5,697,053	A	*	12/1997	Hanly	455/522
5,701,585	A	*	12/1997	Kallin et al.	455/437
5,752,190	A	*	5/1998	Kaewell, Jr. et al.	455/436
5,774,809	A	*	6/1998	Tuutijarvi et al.	455/437
5,812,540	A	*	9/1998	Bruckert et al.	370/332
5,889,768	A	*	3/1999	Storm et al.	370/320

* cited by examiner

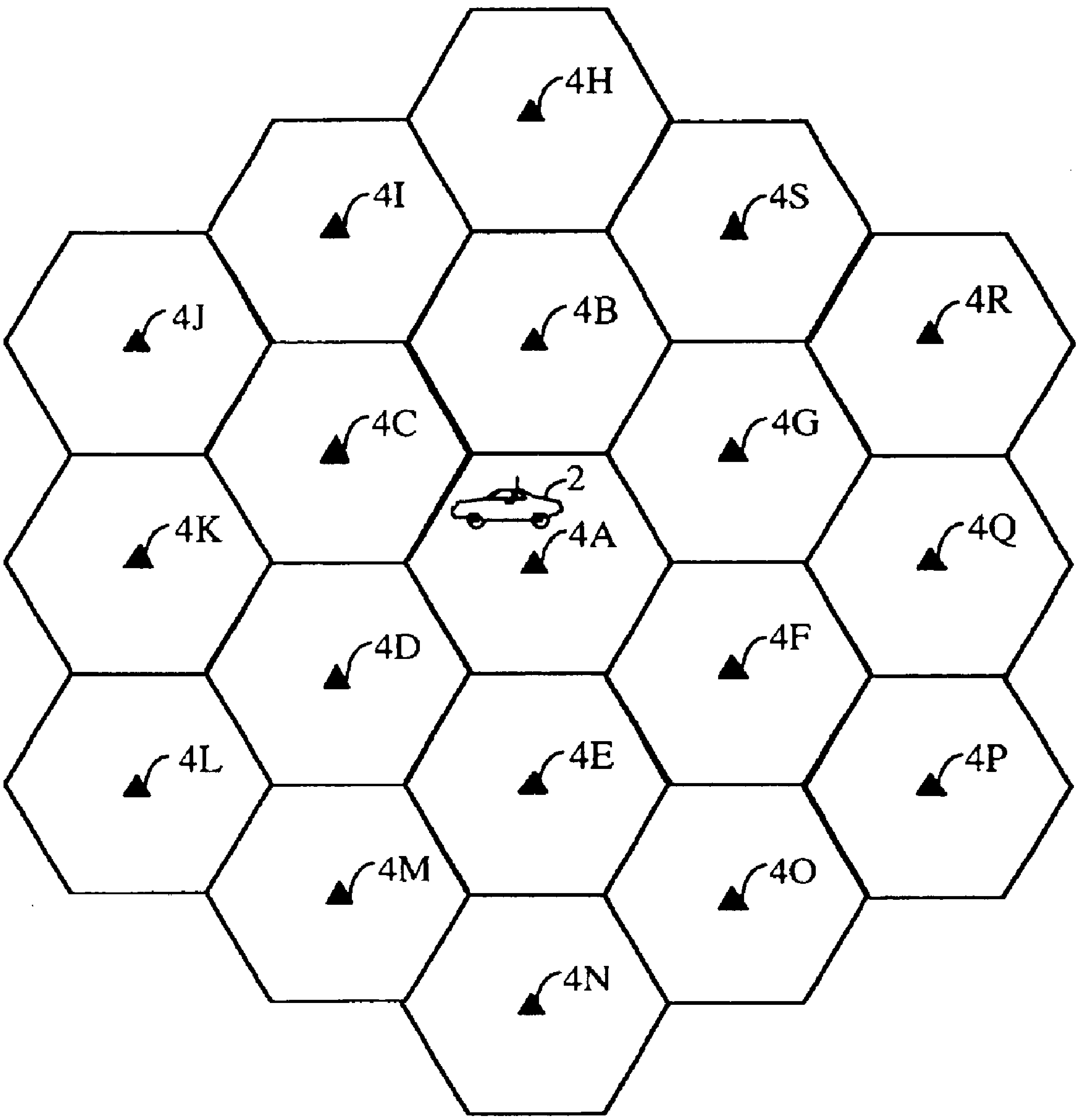


FIG. 1

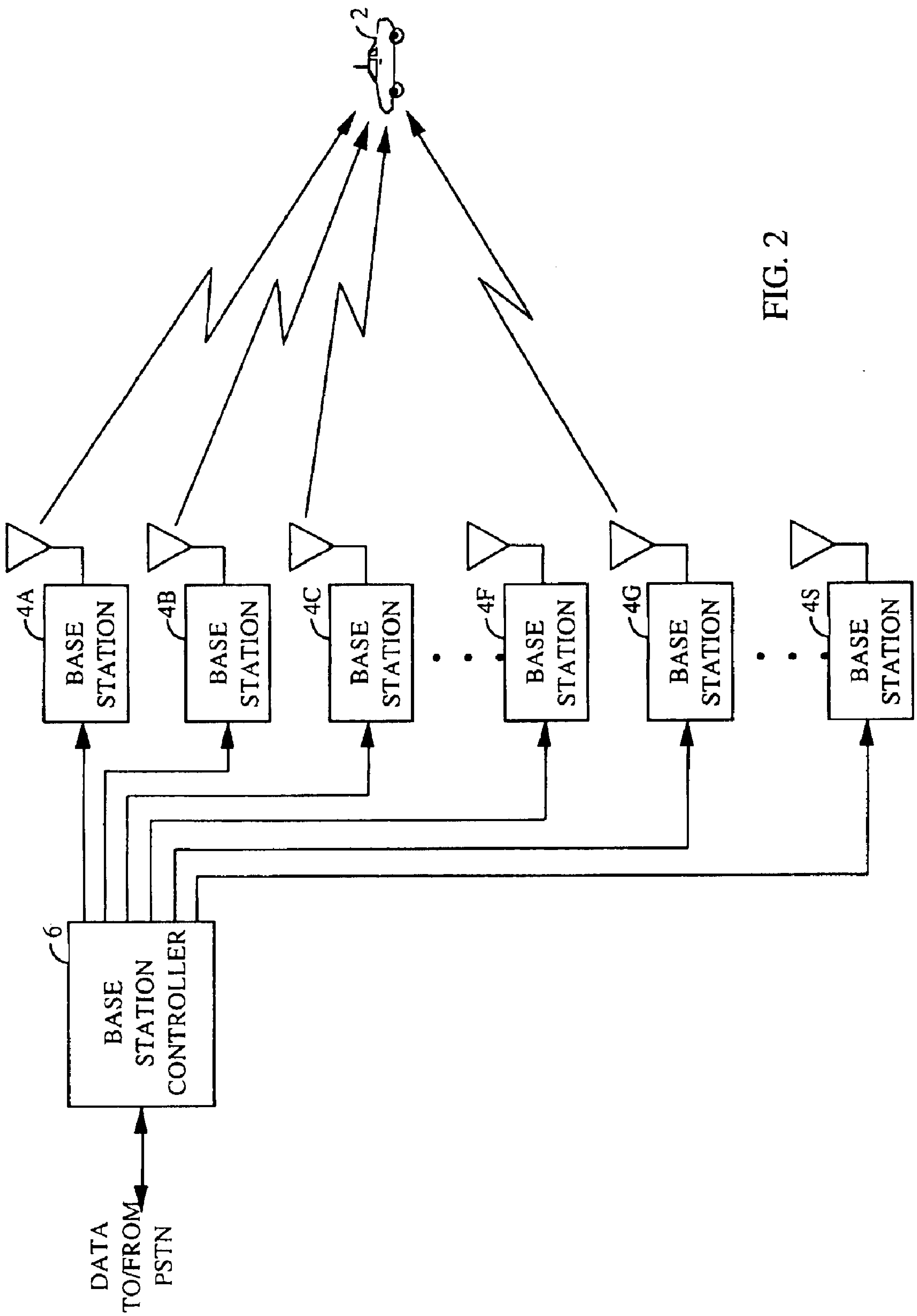

2
BASE STATION
4A
4B
4C
4F
4G
4S
6
BASE STATION CONTROLLER
DATA TO/FROM PSTN

FIG. 2

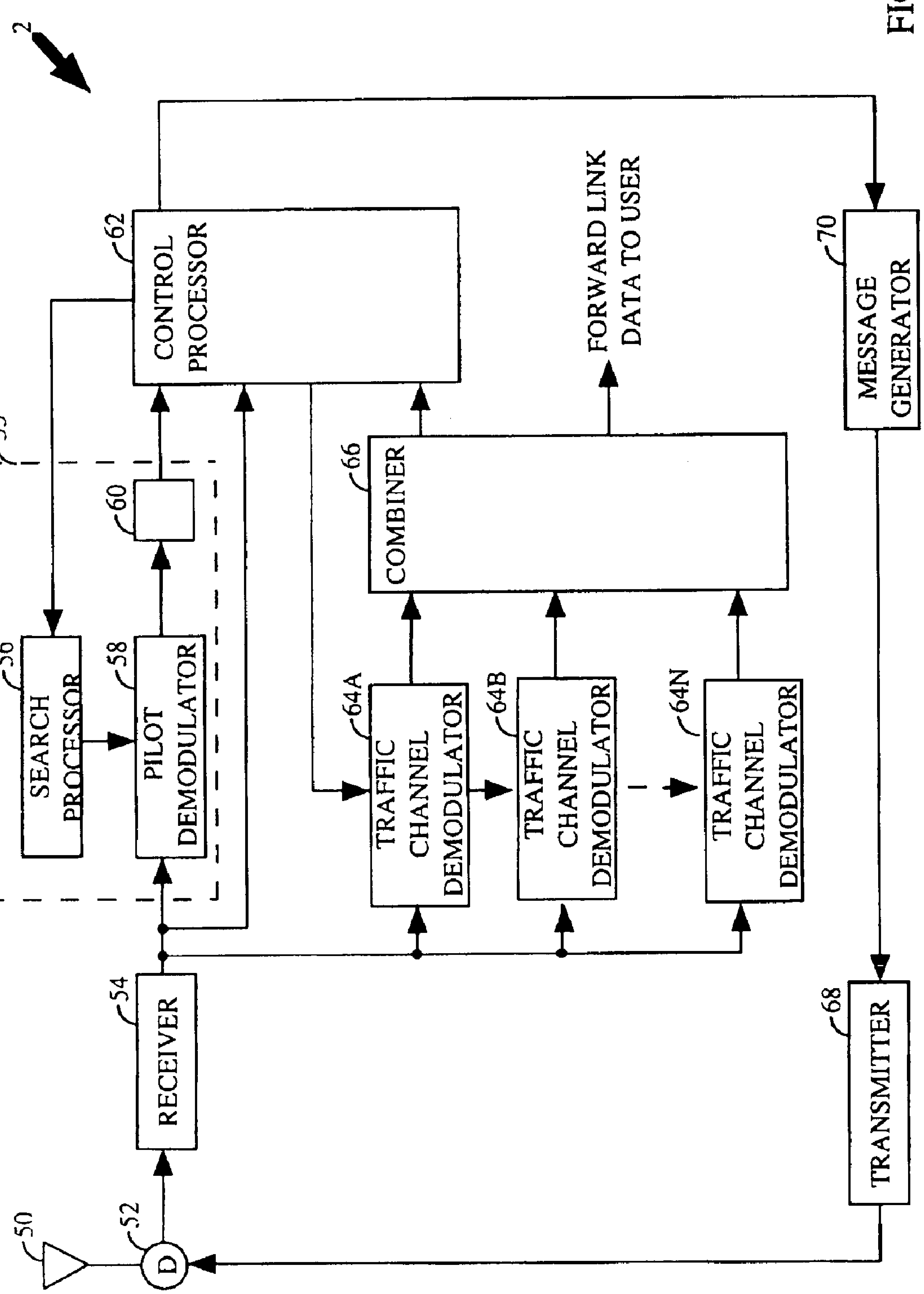

2
50
52
D
54
RECEIVER
55
56
SEARCH PROCESSOR
58
PILOT DEMODULATOR
60
62
CONTROL PROCESSOR
64A
TRAFFIC CHANNEL DEMODULATOR
64B
TRAFFIC CHANNEL DEMODULATOR
64N
TRAFFIC CHANNEL DEMODULATOR
66
COMBINER
FORWARD LINK DATA TO USER
70
MESSAGE GENERATOR
68
TRANSMITTER

FIG. 3

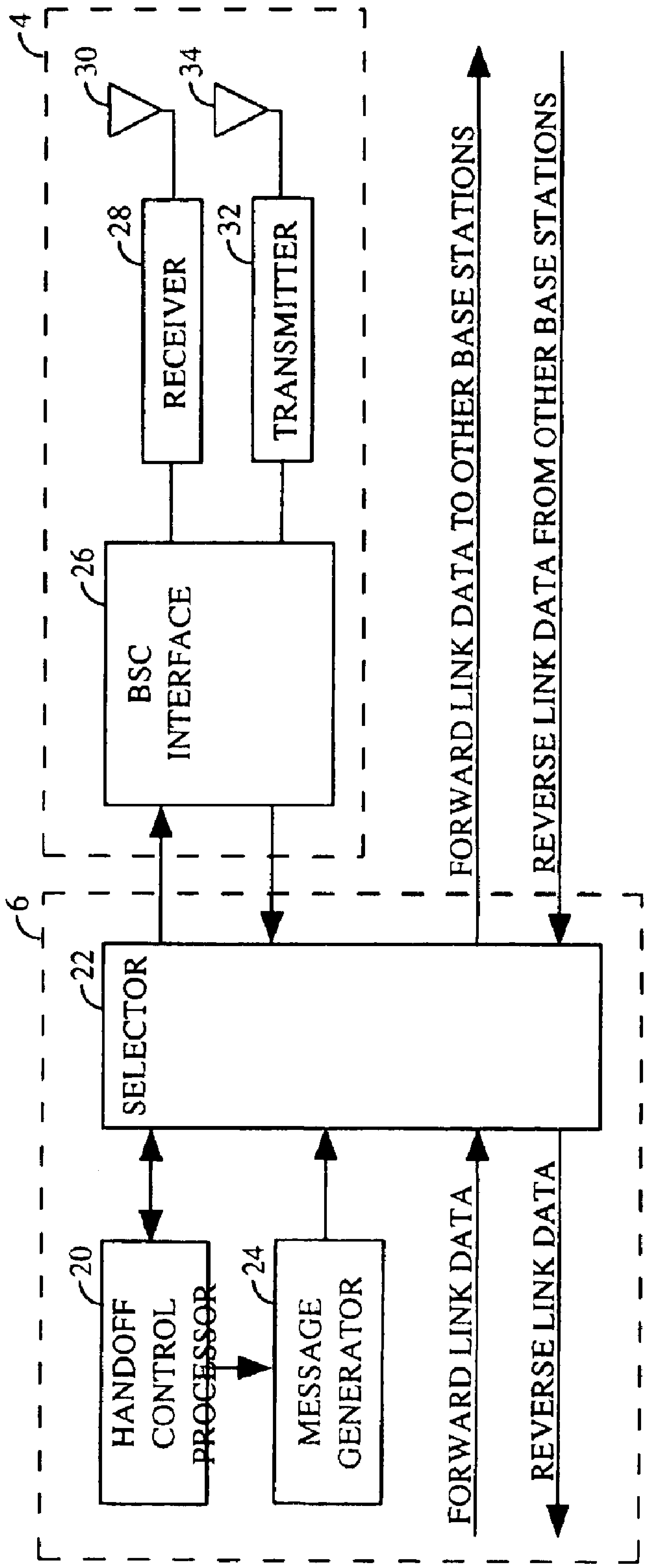

4
30
34
28
RECEIVER
32
TRANSMITTER
26
BSC
INTERFACE
FORWARD LINK DATA TO OTHER BASE STATIONS
REVERSE LINK DATA FROM OTHER BASE STATIONS
6
22
SELECTOR
20
HANDOFF
CONTROL
PROCESSOR
24
MESSAGE
GENERATOR
FORWARD LINK DATA
REVERSE LINK DATA

FIG. 4

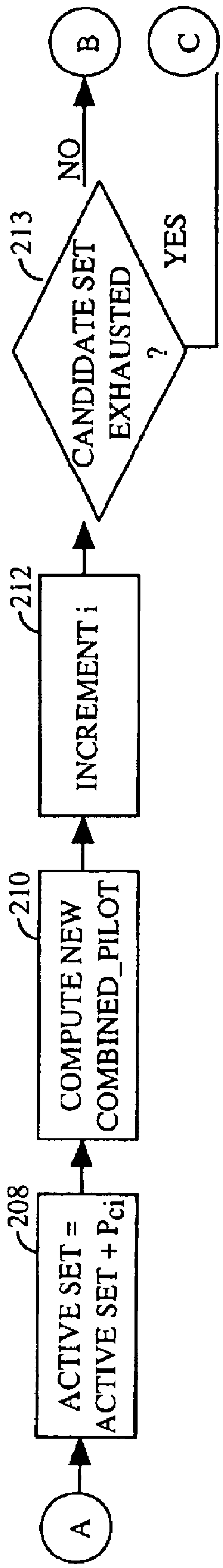

A
208
ACTIVE SET =
ACTIVE SET + P_{ci}
210
COMPUTE NEW
COMBINED_PILOT
212
INCREMENT i
213
CANDIDATE SET
EXHAUSTED
?
NO
YES
B
C

FIG. 6B

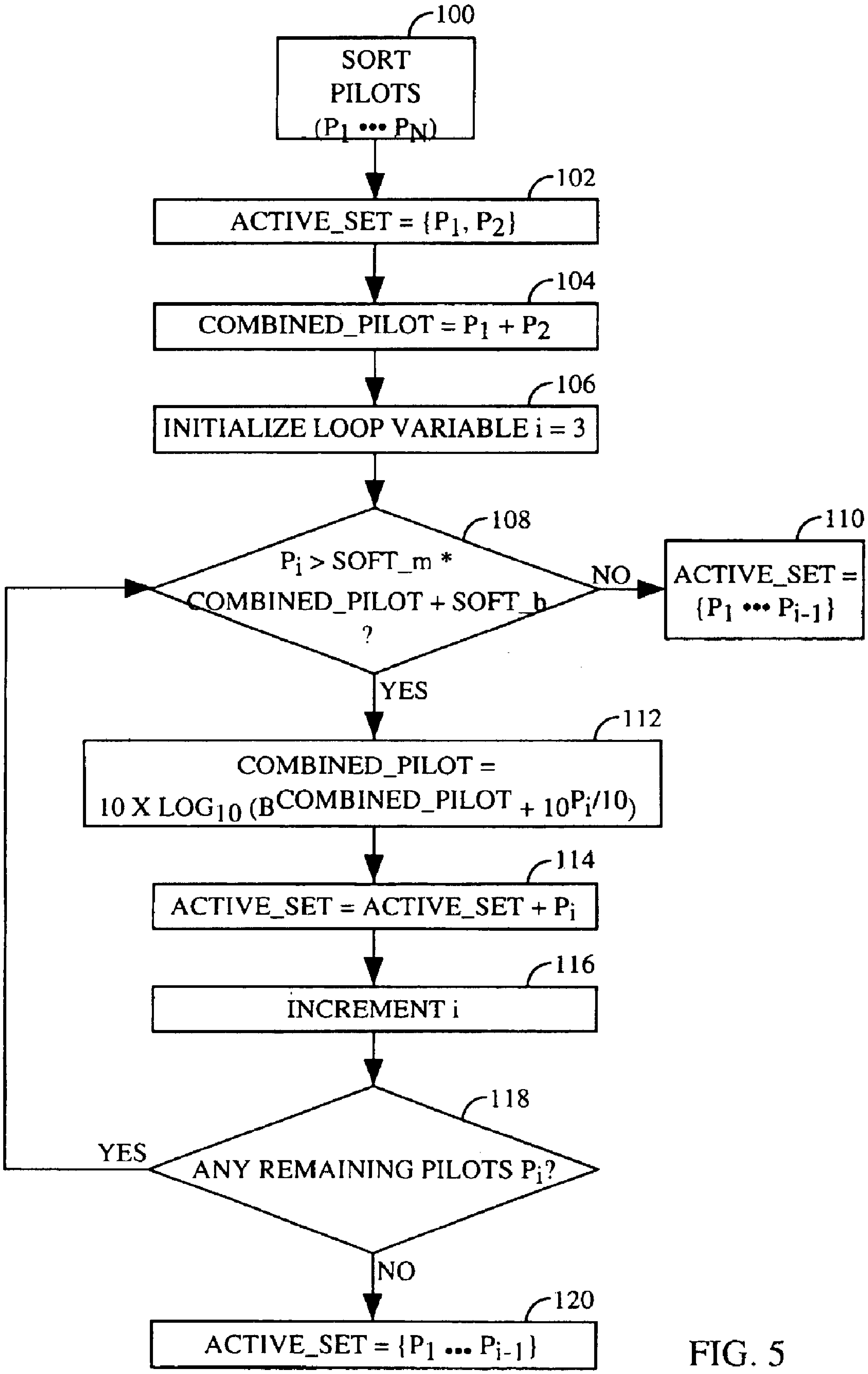

100
SORT PILOTS (P1 ••• PN)
102
ACTIVE_SET = {P1, P2}
104
COMBINED_PILOT = P1 + P2
106
INITIALIZE LOOP VARIABLE i = 3
108
Pi > SOFT_m * COMBINED_PILOT + SOFT_b ?
NO
110
ACTIVE_SET = {P1 ••• Pi-1}
YES
112
COMBINED_PILOT = 10 X LOG10 (BCOMBINED_PILOT + 10Pi/10)
114
ACTIVE_SET = ACTIVE_SET + Pi
116
INCREMENT i
118
ANY REMAINING PILOTS Pi?
YES
NO
120
ACTIVE_SET = {P1 ••• Pi-1}

FIG. 5

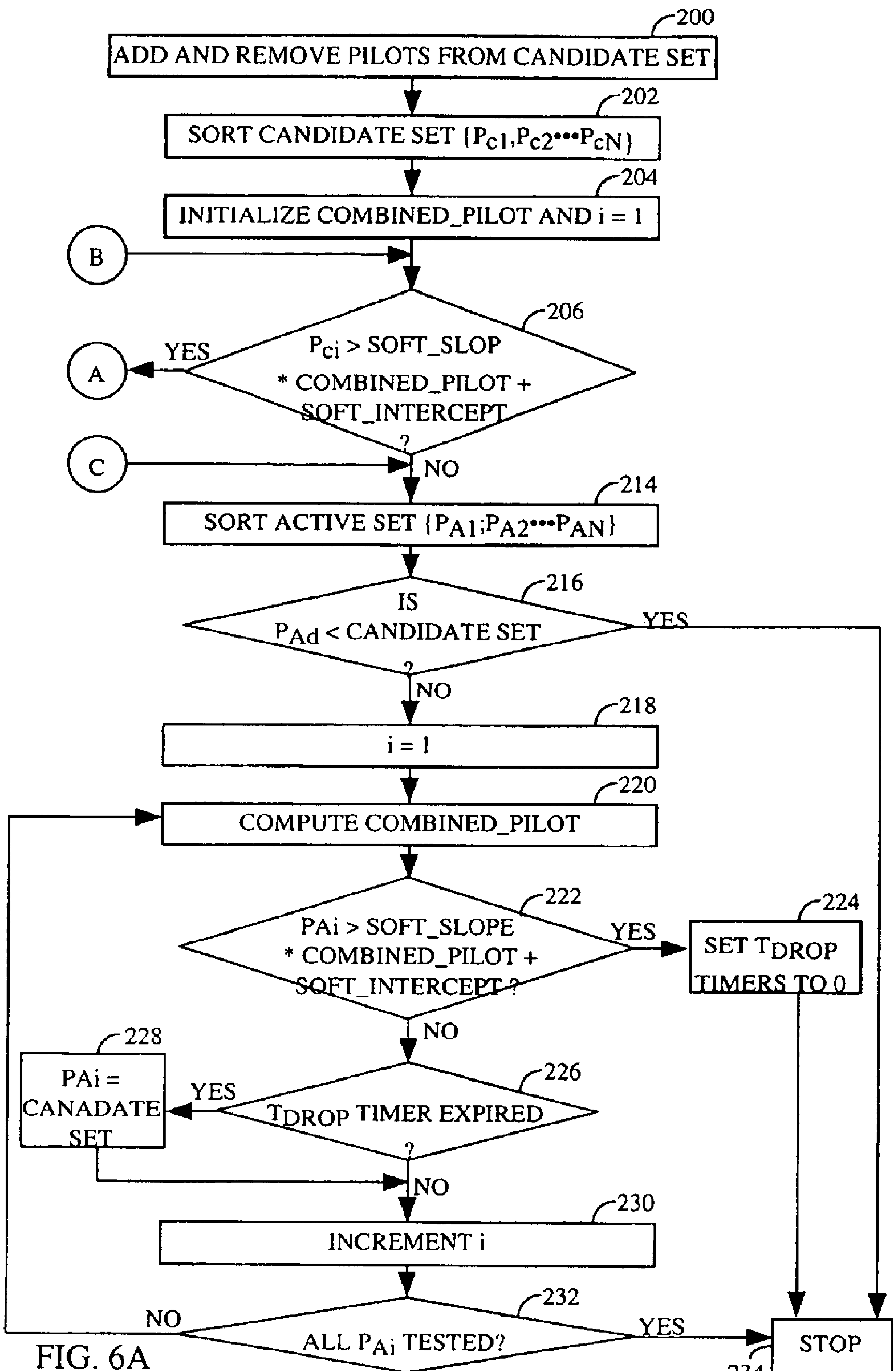

200
ADD AND REMOVE PILOTS FROM CANDIDATE SET
202
SORT CANDIDATE SET {Pc1,Pc2•••PcN}
204
INITIALIZE COMBINED_PILOT AND i = 1
B
206
Pci > SOFT_SLOP * COMBINED_PILOT + SOFT_INTERCEPT ?
YES
A
C
NO
214
SORT ACTIVE SET {PA1;PA2•••PAN}
216
IS PAd < CANDIDATE SET ?
YES
NO
218
i = 1
220
COMPUTE COMBINED_PILOT
222
PAi > SOFT_SLOPE * COMBINED_PILOT + SOFT_INTERCEPT ?
YES
224
SET TDROP TIMERS TO 0
NO
228
PAi = CANADATE SET
YES
226
TDROP TIMER EXPIRED ?
NO
230
INCREMENT i
232
NO
ALL PAi TESTED?
YES
STOP
234

FIG. 6A

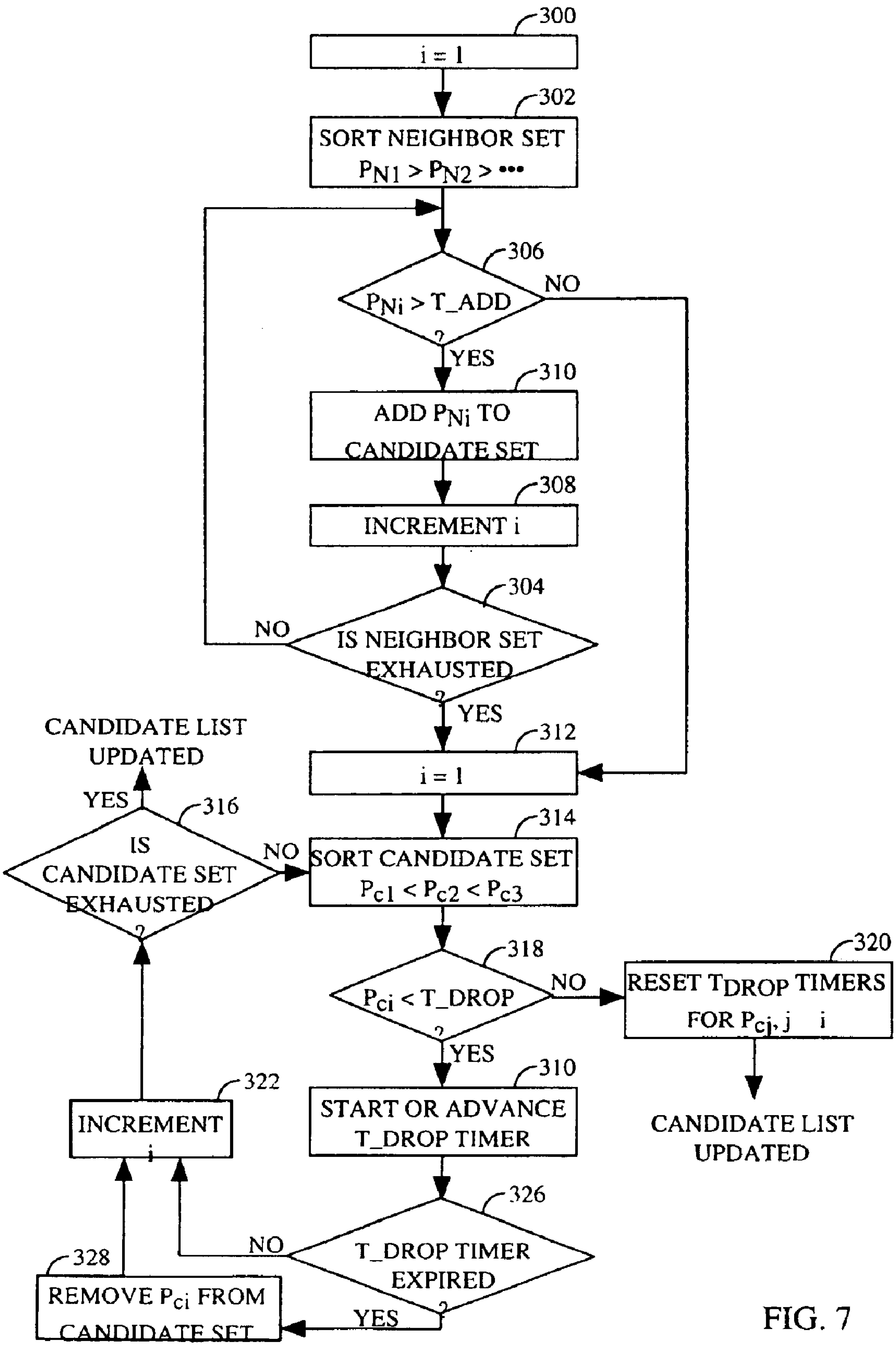

300
i = 1
302
SORT NEIGHBOR SET
PN1 > PN2 > •••
306
PNi > T_ADD ?
NO
YES
310
ADD PNi TO CANDIDATE SET
308
INCREMENT i
304
IS NEIGHBOR SET EXHAUSTED ?
NO
YES
CANDIDATE LIST UPDATED
YES
316
IS CANDIDATE SET EXHAUSTED ?
NO
312
i = 1
314
SORT CANDIDATE SET
Pc1 < Pc2 < Pc3
318
Pci < T_DROP ?
NO
320
RESET TDROP TIMERS FOR Pcj, j i
CANDIDATE LIST UPDATED
YES
310
START OR ADVANCE T_DROP TIMER
322
INCREMENT i
326
T_DROP TIMER EXPIRED ?
NO
YES
328
REMOVE Pci FROM CANDIDATE SET

FIG. 7

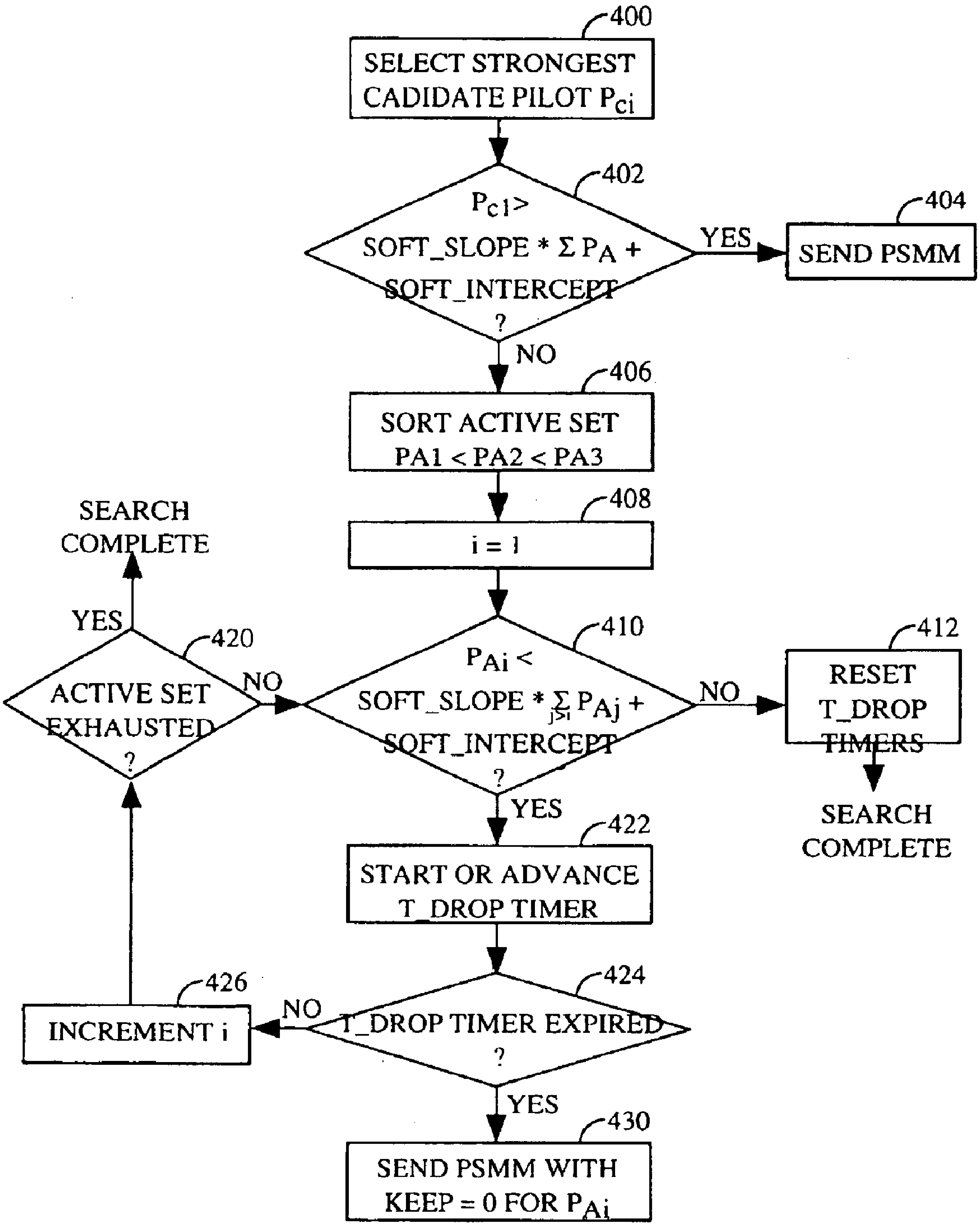

400
SELECT STRONGEST CADIDATE PILOT P_{ci}
402
$P_{c1}>$ SOFT_SLOPE * ΣP_A + SOFT_INTERCEPT ?
YES
404
SEND PSMM
NO
406
SORT ACTIVE SET PA1 < PA2 < PA3
408
i = 1
410
$P_{Ai} <$ SOFT_SLOPE * $\sum_{j>i} P_{Aj}$ + SOFT_INTERCEPT ?
NO
412
RESET T_DROP TIMERS
SEARCH COMPLETE
SEARCH COMPLETE
YES
420
ACTIVE SET EXHAUSTED ?
NO
YES
422
START OR ADVANCE T_DROP TIMER
424
T_DROP TIMER EXPIRED ?
NO
426
INCREMENT i
YES
430
SEND PSMM WITH KEEP = 0 FOR P_{Ai}

FIG. 8

METHOD AND APPARATUS FOR PERFORMING SOFT HAND-OFF IN A WIRELESS COMMUNICATION SYSTEM

Matter enclosed in heavy brackets [ ] appears in the original patent but forms no part of this reissue specification; matter printed in italics indicates the additions made by reissue.

BACKGROUND OF THE INVENTION

I. Field of the Invention

The present invention relates to communication systems. More particularly, the present invention relates to a novel and improved method and system for performing hand-off in a wireless communication system.

II. Description of the Related Art

The use of code division multiple access (CDMA) modulation techniques is but one of several techniques for facilitating communications in which a large number of system users are present. Although other techniques, such as time division multiple access (TDMA), frequency division multiple access (FDMA) and AM modulation schemes such as amplitude companded single sideband (ACSSB) are known, CDMA has significant advantages over these other modulation techniques. The use of CDMA techniques in a multiple access communication system is disclosed in U.S. Pat. No. 4,901,307, entitled "SPREAD SPECTRUM MULTIPLE ACCESS COMMUNICATION SYSTEM USING SATELLITE OR TERRESTRIAL REPEATERS" and U.S. Pat. No. 5,103,459, entitled "SYSTEM AND METHOD FOR GENERATING SIGNAL WAVEFORMS IN A CDMA CELLULAR TELEPHONE SYSTEM", both of which are assigned to the assignee of the present invention and are incorporated by reference. The method for providing CDMA mobile communications was standardized by the Telecommunications Industry Association in TIA/EIA/IS-95-A entitled "Mobile Station-Base Station Compatibility Standard for Dual-Mode Wideband Spread Spectrum Cellular System".

In the just mentioned patents, a multiple access technique is disclosed in which a large number of mobile telephone users, each having a transceiver, communicate through satellite repeaters or terrestrial base stations (also known as cell base stations or cell-sites) using code division multiple access (CDMA) spread spectrum communication signals. In using CDMA communications, the frequency spectrum can be reused multiple times thus permitting an increase in system user capacity. The use of CDMA techniques results in much higher spectral efficiency than can be achieved using other multiple access techniques.

A method for simultaneously demodulating data that has traveled along different propagation paths from one base station and for simultaneously demodulating data redundantly provided from more than one base station is disclosed in U.S. Pat. No. 5,109,390 (the '390 patent), entitled "DIVERSITY RECEIVER IN A CDMA CELLULAR COMMUNICATION SYSTEM", assigned to the assignee of the present invention and incorporated by reference herein. In the '390 patent, the separately demodulated signals are combined to provide an estimate of the transmitted data which has higher reliability than the data demodulated by any one path or from any one base station.

Handoffs can generally be divided into two categories—hard handoffs and soft handoffs. In a hard handoff, when a mobile station leaves an origination cell and enters a destination cell, the mobile station breaks its communication link with the origination cell and thereafter establishes a new communication link with the destination cell. In soft handoff, the mobile station completes a communication link with the destination cell prior to breaking its communication link with the origination cell. Thus, in soft handoff, the mobile station is redundantly in communication with both the origination cell and the destination cell for some period of time.

Soft handoffs are far less likely to drop calls than hard handoffs. In addition, when a mobile station travels near a cell boundary, it may make repeated handoff requests in response to small changes in the environment. This problem, referred to as ping-ponging, is also greatly lessened by soft handoff. The process for performing soft handoff is described in detail in U.S. Pat. No. 5,101,501, entitled "METHOD AND SYSTEM FOR PROVIDING A SOFT HANDOFF IN COMMUNICATIONS IN A CDMA CELLULAR TELEPHONE SYSTEM" assigned to the assignee of the present invention and incorporated by reference herein.

An improved soft handoff technique is disclosed in U.S. Pat. No. 5,267,261, entitled "MOBILE STATION ASSISTED SOFT HANDOFF IN A CDMA CELLULAR COMMUNICATIONS SYSTEM", which is assigned to the assignee of the present invention and incorporated by reference herein. In the system of the '261 patent, the soft handoff process is improved by measuring the strength of "pilot" signals transmitted by each base station within the system at the mobile station. These pilot strength measurements are of assistance in the soft handoff process by facilitating identification of viable base station handoff candidates.

The viable base station candidates can be divided into four sets. The first set, referred to as the active set, comprises base stations which are currently in communication with the mobile station. The second set, referred to as the candidate set, comprises base stations which have been determined to be of sufficient strength to be of use to the mobile station. Base stations are added to the candidate set when their measured pilot energy exceeds a predetermined threshold T_{ADD}. The third set is the set of neighbor set base stations which are in the vicinity of the mobile station (and which are not included in the Active Set or the Candidate Set). And the fourth set is the Remaining Set which consists of all other base stations.

In an IS-95-A communication system, the mobile station sends a Pilot Strength Measurement Message when it finds a pilot of sufficient strength that is not associated with any of the Forward Traffic Channels currently being demodulated or when the strength of a pilot that signal is associated with one of the Forward Traffic Channels being demodulated drops below a threshold for a predetermined period of time. The mobile station sends a Pilot Strength Measurement Message following the detection of a change in the strength of a pilot under the following three conditions:

1. The strength of a neighbor set or Remaining Set pilot is found above the threshold T_{ADD}.
2. The strength of a candidate set pilot exceeds the strength of an active set pilot by more that a threshold (T_{COMP}).
3. The strength of a pilot in the active set of Candidate Set has fallen below a threshold (T_{DROP}) for greater than a predetermined time period.

The Pilot Strength Measurement Message identifies the base station and the measured pilot energy in decibels.

A negative aspect of soft handoff is that because it involves redundantly transmitting information it consumes the available communication resource. However, soft handoff can provide great improvement in the quality of communication. Therefore, there is a need felt in the art for a method of minimizing the number of base stations transmitting redundant data to a mobile station user which provides sufficient transmission quality.

SUMMARY OF THE INVENTION

The present invention is a novel and improved method and apparatus for providing soft handoff in a mobile communication system. It should be noted at the outset, that one of the biggest problems with current systems is that the members of active set are determined in accordance with comparisons of measured pilot energy with fixed thresholds. However, the value of providing a redundant communication link to a mobile station depends strongly on the energy of other signals being provided to the mobile station. For example, the value of redundantly transmitting to a mobile station a signal with received energy of −15 dB will not be of much value, if the mobile station is already receiving a transmission with signal energy of −5 dB. However, redundantly transmitting to a mobile station a signal of received energy of −15 dB may be of substantial value, if the mobile station is receiving transmissions with signal energy of only −13 dB.

In a first embodiment of the present invention, the mobile station under the conditions discussed above transmits a Pilot Strength Measurement Message, which identifies each base station in the active and candidate sets and their corresponding measured pilot energy. The Pilot Strength Measurement Message is received by the base stations in communication with the mobile station. The base stations provide this information to a central control center, referred to as the base station controller.

At the base station controller, the active set is determined in accordance with the combined strength of other pilots in the active set. The base stations controller sorts the pilot signal of the Pilot Strength Measurement Message according to their pilot strength measured at the mobile station. Thus, after sorting the list of base stations consists of $P_1, P_2 \ldots P_N$, where P_1 is the strongest pilot signal and P_N is the weakest. An iterative process is then undertaken to determine which of pilots $P_1, P_2 \ldots P_N$ should be part of the revised active set.

Initially, the revised active set comprises only the strongest pilots P_1 and P_2. When determining whether a pilot P_i should be made part of the active set, a COMBINED_PILOT value is computed. The COMBINED_PILOT value consists of the sum of the energies of the pilots currently in the revised active set ($P_1, P_2 \ldots P_{i-1}$). A threshold is then generated in accordance with the COMBINED_PILOT. In the exemplary, embodiment the threshold is generated by performing a linear operation on the value of COMBINED_PILOT. If the pilot energy value, P_i, exceeds the threshold, it is added to the revised active set and the process is repeated for the next pilot P_{i+1}. If the pilot energy value, P_i, does not exceed the threshold, the revised active set comprises $P_1, P_2 \ldots P_{i-1}$. The revised active set is transmitted to the mobile station and the base station controller then sets up communications with the mobile station in accordance with the revised active set.

In an alternative embodiment, the revised active set is generated in the mobile station. The mobile station continuously measures received pilot strengths of base stations. In determining whether to send a message indicating that a pilot signal from the candidate set should be moved to the active set, the measured pilot energy of a pilot in the candidate set is compared against a threshold generated in accordance with the COMBINED_PILOT as described above. If the strongest pilot signal in the candidate set satisfies the rule, then a message containing all active and candidate set pilots will be sent.

Following the iterative process performed on the members of the candidate set, a second iterative process is performed to determine whether a pilot should be deleted from the revised active set. In this operation, pilots are tested from the weakest member of revised active set to the strongest. A COMBINED_PILOT energy value is computed that is the sum of the energies of all pilots belonging to the active set. A threshold value is generated in accordance with the COMBINED_PILOT value as described above and the pilot signal being tested is compared with the threshold. If a pilot signal strength has been below the threshold value for a predetermined period of time, a message would be sent to the base station indicating that such a pilot signal should be dropped.

The revised active list is transmitted to the base station controller through the base stations with which the mobile station is in communication. The base station sets up the communication links with the base stations in the mobile generated revised active list and transmits an acknowledgment to the mobile station when the links are set up. The mobile station then conducts communications through the base stations of the revised active set.

In the preferred embodiment, the mobile station monitors the pilot signals and in response to the monitored pilot signals the mobile station compiles members of the candidate set. Moreover, the mobile station determines whether a change to the current active set is desirable in view of the criteria discussed above. Upon detecting any change in the desired membership of the active set, the mobile station generates a pilot strength measurement message that, as described above, includes the identities of all pilots in the candidate and active sets and corresponding measured energy values and a corresponding indication whether the pilot should remain in the sets or be dropped into the neighbor set (which is indicated by setting of the KEEP variable described earlier). In the exemplary embodiment, the base station determines the members of the revised active set in accordance with the method described with respect to FIG. **5**.

BRIEF DESCRIPTION OF THE DRAWINGS

The features, objects, and advantages of the present invention will become more apparent from the detailed description set forth below when taken in conjunction with the drawings in which like reference characters identify correspondingly throughout and wherein:

FIG. **1** is an illustration of a cellular communication network;

FIG. **2** is an illustration of the cellular communication network of FIG. which includes the base station controller;

FIG. **3** is a block diagram of the mobile station of the present invention;

FIG. **4** is a block diagram of the base station of the present invention;

FIG. **5** is a flow diagram of the method for generating the revised active set in the base station controller;

FIG. **6** is a flow diagram of the method for generating the revised active set in the mobile station;

FIG. **7** is flow diagram illustrating the preferred method of generating the candidate set in the mobile station; and

FIG. **8** is a flow diagram illustrating the preferred method of the present invention wherein a change in the preferred members of active set is detected and a pilot strength measurement message is transmitted to the base station in response to the detected changed.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

FIG. **1** illustrates a wireless communication network in which the geographical area has been divided up into coverage areas referred to as cells and illustrated by a set of adjacent hexagons. Each cell is served by a corresponding base station **4**. Each base station transmits a pilot signal which uniquely identifies that base station. In the exemplary embodiment, the base stations **4** are CDMA base stations. A detail description of soft handoff in a wireless CDMA communication system is described in detail in the aforementioned U.S. Pat. Nos. 5,101,501 and 5,267,261.

Mobile station **2** is located within the cell served by base station **4**A. Since mobile station **2** is located near the cell boundary, it will likely be in a soft hand-off condition, in which it is simultaneously in communication with more than one base station. It may, for example, be in communication with base stations **4**A and **4**B. Thus, base stations **4**A and **4**B are said to make up the active set. Moreover, it may be that mobile station **2** has determined that other base stations in its vicinity have a measured pilot energy above a predetermined threshold TADD, but that those base stations are not currently in communication with the mobile station. The pilot signals of those base stations are said to make up the candidate set. The candidate set could be made up of base stations **4**C and **4**G.

Referring to FIG. **2**, a typical communication network is illustrated, data directed mobile station **2** is provided from a public switched telephone network or other wireless system not shown) to base station controller **6**. Base station controller **6** provides the data to the base stations in mobile station **2**'s active list. In the example, base station controller **6** redundantly provides data to and receives data from base stations **4**A and **4**B. The present invention is equally applicable to conditions where each cell is divided into sectors. Communications to and from each sector can be separately received and demodulated by mobile station **2**. For simplicity, the discussion will be described wherein in each base of base station **4** are uniquely located base stations. However, it will be readily seen by one skilled in the art that the present invention is equally applicable to sectored cells, simply by considering the possibility that the base stations can be co-located and transmitting to separate sectors within a cell. The condition where a mobile station is in simultaneous communication with more than one sector of a cell is referred to as softer handoff. The method and apparatus for performing softer hand-off are described in detail in copending U.S. patent application Ser. No. 08/144,903, entitled "METHOD AND APPARATUS FOR PERFORMING HANDOFF BETWEEN SECTORS OF A COMMON BASE STATION", filed Oct. 30, 1993, which is assigned to the assignee of the present invention and incorporated by reference herein.

Within mobile station **2**, each copy of the data packet is separately received, demodulated and decoded. The decoded data is then combined to give an estimate of the data of greater reliability than any of demodulated estimates of the data.

FIG. **3** illustrates mobile station **2** of the present invention. Mobile station **2** continuously or at intermittent intervals measures the strength of pilot signals of base stations **4**. Signals received by antenna **50** of mobile station **2** are provided through duplexer **52** to receiver (RCVR) **54** which amplifies, down converts, and filters the received signal and provides it to pilot demodulator **58** of searcher subsystem **55**.

In addition, the received signal is provided to traffic demodulators **64**A–**64**N. Traffic demodulators **64**A–**64**N, or a subset thereof, separately demodulate signals received by mobile station **2**. The demodulated signals from traffic demodulators **64**A–**64**N are provided to combiner **66** which combines the demodulated data, which in turn provides an improved estimate of the transmitted data.

Mobile station **2** measures the strength of pilot signals. Control processor **62** provides acquisition parameters to search processor **56**. In the exemplary embodiment of a CDMA communication system, control processor **62** provides a PN offset to search processor **56**. Search processor **56** generates a PN sequence which is used by pilot demodulator **58** to demodulate the received signal. The demodulated pilot signal is provided to energy accumulator **60** which measures the energy of the demodulated pilot signal, by accumulating the energy for predetermined lengths of time.

The measured pilot energy values are provided to control processor **62**. In the exemplary embodiment, control processor **62** compares the energy values to thresholds T_{ADD} and T_{DROP}. T_{ADD} is a threshold value above which the received signal is of sufficient strength to effectively provide communications with mobile station **2**. T_{DROP} is a threshold value below which the received signal energy is insufficient to effectively provide communications with mobile station **2**.

Mobile station **2** transmits a Pilot Strength Measurement Message which includes all pilot signals with energy greater than T_{ADD} and all members of the current active set whose measured pilot energy have not fallen below T_{DROP} for more than a predetermined time period. In the exemplary embodiment, mobile station **2** generates and transmits a Pilot Strength Measurement Message following the detection of a change in the strength of a pilot under the following three conditions:

1. The strength of a neighbor Set or Remaining Set pilot is found above the threshold T_{ADD}.
2. The strength of a Candidate Set pilot exceeds the strength of an Active Set pilot by more that a threshold (T_{COMP}).
3. The strength of a pilot in the Active Set has fallen below a threshold (T_{DROP}) for greater than a predetermined time period.

In the exemplary embodiment, the Pilot Strength Measurement Message identifies the pilot signal and provides a corresponding measured pilot energy. In the exemplary embodiment, the base stations in the Pilot Strength Measurement Message are identified by their pilot offsets and their corresponding measured pilot energy is provided in units of decibels.

Control processor **62** provides the identities of the pilots and their corresponding measured pilot energies to message generator **70**. Message generator **70** generates a Pilot Strength Measurement Message containing the information. The Pilot Strength Measurement Message is provided to transmitter (TMTR) **68**, which encodes, modulates, upconverts and amplifies the message. The message is then transmitted through duplexer **52** and antenna **50**.

Referring to FIG. **4**, the Pilot Strength Measurement Message is received by antenna **30** of base station **4** and provided to receiver (RCVR) **28**, which amplifies, down converts, demodulates and decodes the received signal and provides the message to base station controller (BSC) interface **26**. Base station controller (BSC) interface **26** sends the message to base station controller (BSC) **6**. The message is provided to selector **22**, which may also receive the message redundantly from other base stations which are in communication with mobile station **2**. Selector **22** combines message estimates received from the base stations in communication with mobile station **2** to provide an improved packet estimates.

Selector **22** provides the power strength measurement message to hand-off control processor **20**. In the first exemplary embodiment, hand-off control processor **20** selects the base stations which will communicate with mobile station **2**, that is the members of the revised active set, in accordance with the method provided in FIG. **5**.

In block **100**, hand-off control processor **20** sorts pilots in the Pilot Strength Measurement Message according to their strengths. So, for example, P_1 would be the strongest received pilot, P_2 would be the second strongest pilot and so on. In block **102**, the revised active set (ACTIVE_SET) is set to include P_1 and P_2. In block **104**, the variable COMBINED_PILOT is set to the sum of the energies of P_1 and P_2. In block **106**, the loop variable i is set to 3.

In block **108**, the energy of the pilot signal of the ith strongest received signal (P_i) is compared against a threshold value to determine whether it should be added to the revised active set. In the exemplary embodiment, the threshold (T) is determined in accordance with equation (1) below:

$$T = SOFT\_SLOPE * COMBINED\_PILOT + SOFT\_INTERCEPT \quad (1)$$

In the exemplary embodiment, SOFT_SLOPE is set to 2.25 and SOFT_INTERCEPT is set to 3.0. The values of SOFT_SLOPE and SOFT_INTERCEPT can be parameters that are sent over the air to the mobile station or selected values could be programmed into the mobile station. The values of SOFT_SLOPE and SOFT_INTERCEPT can be determined in accordance with factors such as the amount of soft handoff which is acceptable to a network manager and empirical studies on the quality of transmission links. If the energy value P_i is less than the threshold value, then the flow proceeds to block **110** and the revised active set includes the signals corresponding to the pilots $\{P_1 \ldots P_{i-1}\}$.

If the energy value P_i is greater than the threshold value in block **108**, then the flow proceeds to block **112**. In block **112**, a new COMBINED_PILOT is computed by summing the value of the energy of the ith strongest signal in the pilot strength measurement message (P_i) with the current value of COMBINED_PILOT. Because in the exemplary embodiment, the energy of the pilot signals is provided in decibels, the energies must be converted to linear representations before being summed and put back into decibel form. In block **114**, P_i is added to the revised active set.

In block **116**, the loop variable (i) is incremented. In block **118**, hand off control processor **20** checks to determine whether all base stations in the pilot strength measurement message have been tested. If there are no remaining pilots to test, then the flow proceeds to block **120** and the revised active set comprises all the base stations in the pilot strength measurement message. If, in block **118**, there are base stations in the pilot strength measurement message which remain to be tested, the flow returns to block **108** and proceeds as described above.

After generating the revised active set, base station controller **6** determines whether the base stations in the revised active list can accommodate communications with mobile station **2**. If any of the base stations in the revised active set cannot accommodate communications with mobile station **2**, they are removed from the revised active set. After generating the revised active set, hand-off control processor **20** provides the information to selector **22** indicating the members in the revised active set. In response to the revised active set provided by hand-off control processor **20**, selector **22** allocates traffic channels for performing communications to the mobile station using the base stations in the revised active set.

Hand-off control processor **20** provides a message indicating the revised active set to message generator **24**. Message generator **24** generates a message for transmission to mobile station **2**, referred to as the handoff direction message. The handoff direction message indicates the base stations in the revised active set and corresponding channels those base stations will use to communicate with mobile station **2**. The message is provided through selector **22** and provided to the base stations which were in communication with mobile station **2** prior to the generation of the revised active set. The base stations in communication with mobile station **2** transmit the handoff direction message to mobile station **2**.

Referring back to FIG. **3**, the handoff direction message is received by antenna **50** of mobile station **2**. It is provided to receiver **54**, which amplifies, downconverts, demodulates and decodes the message and provides it to control processor **62**. Control processor **62** then configures the traffic channel demodulators **64A–64N** to demodulate traffic channels in accordance with the revised active set specified in the handoff direction message.

In an alternative embodiment of the present invention, the revised active set is generated at mobile station **2**. This alternative embodiment, provides more timely generation of the revised active set. Because the Pilot Strength Measurement Message is only transmitted under the three conditions described above, update of the active set may be undesirably delayed. However, the alternative embodiment results in transmission of the pilot strength measurement message in a more timely fashion.

In the alternative embodiment, mobile station **2** measures received pilot energy as described above. The pilot energy values are provided to control processor **62**. In response, control processor **62** generates a revised active set. If the revised active set differs from the current active set, mobile station **2** transmits a message indicating the members of the revised active set to base station controller **6** through base stations **4**. Base station controller **6** sets up communications with mobile station **2**. Mobile station **2** reconfigures traffic channel demodulators **64A–64N** to demodulate received signals in accordance with the mobile generated revised active set.

In the exemplary embodiment, control processor **62** in mobile station **2** generates the revised active set in accordance with the method shown in FIG. **6**. In block **200**, pilots with measured energy in excess of threshold T_{ADD} are added to the candidate set and pilots whose measured energy has fallen below T_{DROP} for more that a predetermined time period are removed from the candidate list. In the exemplary embodiment, the time period during which a pilot is below T_{DROP} is tracked by a timer within control processor **62** referred to herein as the T_{DROP} timer.

In block **202**, the pilots in the candidate list are sorted from strongest to weakest. Thus, P_{C1} is stronger than P_{C2}, and so on. In block **204**, the variable COMBINED_PILOT is set equal to the energy of all pilots in the active set. Also, in block **204**, loop variable (i) is initialized to the value 1. In block **206**, the candidate set member P_{Ci} is tested to determine whether it should be made part of the revised active set. P_{Ci} is compared against a threshold generated in accordance with the current value of COMBINED_PILOT. In the exemplary embodiment, threshold (T) is generated in accordance with equation (1) above.

If the pilot energy of P_{Ci} exceeds threshold T, then the flow moves to block **208**. In block **208**, pilot P_{Ci} is added to the revised active set. In block **210**, a new value of COMBINED_PILOT is computed which is equal to the old value of COMBINED_PILOT plus the energy of pilot P_{Ci}. In block **212**, the loop variable (i) is incremented.

In block **213**, it is determined whether all pilots in the candidate set have been tested. If all pilots in the candidate set have not been tested, then the flow moves to block **200** and proceeds as described above. If all pilots in the candidate set have been tested or if, back in block **206**, the pilot energy of P_{Ci} did not exceed threshold T, then the flow moves to block **214**. In block **214**, the revised active set is sorted from lowest energy to highest energy. Thus, P_{A1} has the minimum measured energy in the revised active set, P_{A2} has the second lowest and so on up to the last member of the revised active set P_{AN}.

In block **216**, it is determined whether P_{A1} is a member of the candidate set. If P_{A1} is a member of the candidate set then the flow moves to block **234** and the revision of the active set is complete. In block **218**, loop variable i is set to 1. In block **220**, COMBINED PILOT for testing P_{Ai} is computed. The value of COMBINED_PILOT is set equal to the sum of the measured energy of all pilots having energy greater than the pilot currently being tested. Thus, COMBINED_PILOT is determined by the equation:

$$\text{COMBINED\_PILOT} = \sum_{j=i+1}^{N} P_{Aj} \qquad (2)$$

In block **222**, the current pilot being tested is compared against a threshold (T) determined in accordance with the computed value of COMBINED_PILOT. In the exemplary embodiment, threshold T is determined in accordance with equation (1) above. If the measured pilot energy P_{Ai} exceeds threshold T, then the flow moves to block **224** and the drop timers for pilots P_{Ai} to P_{AN} are reset to zero and determination of the revised active set ends in block **234**.

If the measured pilot energy P_{Ai} does not exceed threshold T, then the flow moves to block **226**. In block **226**, it is determined whether the T_{DROP} timer for P_{Ai} has expired. If the T_{DROP} timer has expired, then, in block **228**, the pilot P_{Ai} is removed from the revised active set and put in the candidate set and the flow proceeds to block **230**. If in block **226**, it is determined that the T_{DROP} timer for P_{Ai} has not expired, then the flow proceeds directly to block **230**. In block **230**, the loop variable (i) is incremented. Then, in block **232**, it is determined whether all the pilots in the revised active set P_{Ai} have been tested. If all the pilots in the revised active set have been tested, then the flow proceeds to block **234** and generation of the revised active set is complete. If all the pilots in the revised active set have not been tested, then the flow proceeds to block **220** and proceeds as described above.

Referring now to FIGS. **7** and **8**, a preferred method for implementing the present invention is illustrated. In the preferred embodiment, the mobile station monitors the pilot signals and in response to the monitored pilot signals the mobile station compiles members of the candidate set. Moreover, mobile station determines whether a change to the current active set is desirable in view of the criteria discussed above. Upon detecting any change in the desired membership of the active set, the mobile station generates a pilot strength measurement message that, as described above, includes the identities of all pilots in the candidate and active sets corresponding measured energy values and a corresponding indication whether the pilot should remain in the sets or be dropped into the neighbor set (which is indicated by setting of the KEEP variable described earlier). In the exemplary embodiment, the base station determines the members of the revised active set in accordance with the method described with respect to FIG. **5**.

The preferred embodiment provides for timely modification to the members of the active set and provides for determination of the members of the revised active set at the base station, which reduces computations at the mobile station and allows the selection process to include capacity constraints of the base stations. Capacity constraints of the base stations can be taken into account by the base station controller simply by removing or weighting pilot signals which are transmitted by base stations under high capacity load conditions.

FIG. **7** is a flowchart illustrating the method for updating the candidate set, which in the exemplary embodiment is performed within the mobile station. In block **300**, the loop variable (i) is initialized to the value 1. In block **302**, the pilots of the neighbor set (P_N) are sorted such that $P_{N1}>P_{N2}>P_{N3}$, and so on. In block **306**, the neighbor set pilot currently being tested (P_{Ni}) is compared with the threshold T_{ADD}. If the pilot signal energy (P_{Ni}) does not exceed the threshold, then, in block **306**, the flow proceeds directly to block **312**. If the pilot signal energy (P_{Ni}) exceeds the threshold then in block **310** the pilot signal is added to the candidate set and the flow proceeds to block **308**.

In block **308**, the index number of the neighbor set pilot being tested is incremented. Then, in block **304**, it is determined whether all members of the neighbor set have been tested. If all members of the neighbor set have not been tested, then the flow moves to block **306** and proceeds as described before. If all members of the neighbor set have been tested, then the flow moves to block **312**.

In block **312**, the index variable (i) is reset to 1. Then, in block **314**, the pilots in the candidate set (P_C) are sorted from weakest to strongest, such that $P_{C1}<P_{C2}<P_{C3}$, and so on. In block **318**, the energy of the candidate list being tested (P_{Ci}) is compared to the drop threshold T_{DROP}. If the energy is below the drop threshold, then the flow proceeds to block **310**. If the energy is above the drop threshold, then the flow proceeds to block **320**. Since the list of pilots is sorted, all the remaining members to be tested are necessarily greater than T_{DROP}. So, in block **320**, the T_{DROP} timers for P_{Ci} and all pilots stronger than (P_{Ci}) are reset and the update of the candidate set is complete.

As described above the T_{DROP} timer is a timer that keeps track of the time that a pilot has been below the drop threshold. The purpose of the T_{DROP} timer is to avoid mistakenly dropping a strong pilot which may have a weak measured energy due to short duration change in the propagation environment, such as a fast fade. In block **310**, the T_{DROP} timer is started if the timer for P_{Ci} is not already running or advanced if it is.

In block **326**, a test made to determine whether the T_{DROP} timer for the pilot (P_{Ci}) has expired. If the timer has expired, then the flow moves to block **328** and the pilot (P_{Ci}) is removed from the candidate set. Then the flow moves to block **322**. Also, if the timer had not expired in block **326**, the flow moves directly to block **322**. In block **322**, the candidate set index variable (i) is incremented. Then, in block, **316**, it is determined whether all pilots in the candidate set have been tested. If all members of the candidate set have been tested the candidate set update is complete. If less than all members of the candidate set have been tested, the flow moves to block **314** and proceeds as described above.

In the preferred embodiment, the selection of the candidate set members is performed in the mobile station. This is because selection of the candidate set, typically, does not require knowledge of capacity constraints of the base stations in the network. However, in an alternative embodiment, the method for dropping candidate set members to the neighbor set may be performed in the base station controller. Moreover, addition of members to the candidate set could be performed in the base station controller provided the base station controller has knowledge of or is provided with knowledge of the members of the mobile station's neighbor set.

FIG. **8** illustrates the method for detecting the need to revise the active set, which in the preferred embodiment is performed in the mobile station. In block **400**, the strongest pilot in the candidate set (P_{C1}') is selected. Note the prime is to differentiate the pilot from P_{C1} referred to in FIG. **7** which represented the weakest candidate set pilot. In block **402**, the energy of (P_{C1}) is compared to a threshold (T) which is based on the cumulative energy of the pilots in the active set, as shown in Equation 3 below:

$$T=f(\Sigma P_{Ai})=SOFT\_SLOPE*\Sigma P_{Ai}+SOFT\_ADD\_INTERCEPT \quad (3)$$

If (P_{C1}') exceeds the threshold (T), then the mobile station transmits the pilot strength measurement message to the base station, in block **404**.

If (P_{C1}') does not exceed the threshold (T), then the flow proceeds to block **406**. In block **406**, the active set is sorted from weakest pilot to strongest pilot. In block **408**, the active set index variable (i) is set to 1. Then in block **410**, the active set pilot (P_{ai}), which is being tested to determine whether it should remain in the active set, is tested against a threshold (T) generated in accordance with a sum of energies of all stronger pilots as shown in equation (4) below:

$$\begin{aligned} T &= f\left(\sum_{j>i} P_{Aj}\right) \\ &= SOFT\_SLOPE \sum_{j>i} P_{Aj} + SOFT\_DROP\_INTERCEPT \end{aligned} \quad (4)$$

If the pilot being tested (P_{Ai}) exceeds the threshold (T), then it and all pilots of strength greater than it should remain in the active set. Thus, in block **412** the T_{DROP} timers for all pilots with strength greater than P_{Ai} are reset and the current search for a revision of the active set is complete, with no need for revision detected by the mobile station. In the preferred embodiment, the intercept value (SOFT_ADD_INTERCEPT) used to generate the add threshold is permitted to be of a value different from the intercept value SOFT_DROP_INTERCEPT used to generate the drop threshold. This provides for greater flexibility and allows the network to introduce additional hysteresis into the signal levels.

If the pilot (P_{Ai}) is less than the threshold (T), then the flow proceeds to block **422**. In block **422**, the T_{DROP} timer for pilot (P_{Ai}) is started if not running and advanced if already running. In block **424**, whether the T_{DROP} timer for pilot (P_{Ai}) has expired is tested. If the T_{DROP} timer has expired, then the mobile station transmits a pilot strength measurement message to the base station in block **430**. If the T_{DROP} timer has not expired, then the flow moves to block **426** where the active set pilot index (i) is advanced. Then, the flow moves to block **420**, where it is determined whether all active set members have been tested. If all active set members have been tested, then the search ceases with no need to revise the active set detected. If less than all of the members of the active set have been tested, the flow moves to block **410** and proceeds as described previously.

The previous description of the preferred embodiments is provided to enable any person skilled in the art to make or use the present invention. The various modifications to these embodiments will be readily apparent to those skilled in the art, and the generic principles defined herein may be applied to other embodiments without the use of the inventive faculty. Thus, the present invention is not intended to be limited to the embodiments shown herein but is to be accorded the widest scope consistent with the principles and novel features disclosed herein.

We claim:

1. A method for selecting base stations to communicate with a remote station comprising:

computing a threshold value in accordance with a combination of measurements of signal energies from base stations capable of communicating with said remote station;

comparing a signal energy measurement of a first base station with said threshold value; and

selecting said first base station when said signal energy measurement of said first base station exceeds said threshold value;

wherein said combination of signal energy measurements from base stations capable of communicating with said remote station comprises the sum of pilot energy values of pilot with greater received energy than said first base station.

2. The method of claim **1** wherein said step of computing a threshold value comprises performing a linear operation upon said combination of signal energy measurements from base stations capable of communicating with said remote station.

3. In a wireless communications system wherein a first base station transmits a first pilot signal and a first traffic signal, and a second base station transmits a second pilot signal and a second traffic signal, and a remote station receives said first pilot signal and said first traffic signal, a method for determining whether to add a third base station to an Active Set of said remote station, comprising the steps of:

demodulating said first pilot signal;

measuring the energy of said demodulated first pilot signal;

generating a threshold in accordance with said demodulated first pilot signal energy;

demodulating said second pilot signal;

measuring the energy of said demodulated second pilot signal;

comparing said demodulated second pilot signal energy with said threshold;

adding said second base station to said Active Set when said demodulated second pilot signal energy exceeds said threshold;

generating a revised threshold in accordance with a combination of said demodulated first pilot signal energy and said demodulated second pilot signal energy;

demodulating a third pilot signal from said third base station;

measuring the energy of said demodulated third pilot signal;

comparing said demodulated third pilot signal energy with said revised threshold; and

adding said third base station to said Active Set when said demodulated third pilot signal energy exceeds said revised threshold.

4. In a wireless communications system in which a plurality of base stations are in communication with a base station controller, a method for determining an Active Set of base stations to communicate with a remote station at said base station controller, comprising the steps of:

receiving a signal strength measurement message indicative of the signal strengths associated with each of said plurality of base stations as measured at said remote station;

selecting a first base station as a member of said Active Set of base stations;

calculating a threshold value in accordance with a signal strength of said selected first base station;

selecting a second base station as a member of said Active Set of base stations in accordance with said threshold value;

summing the signal strengths associated with each of said two selected base stations;

determining a revised threshold value in accordance with said summed signal strengths; and

determining remaining members of said Active Set in accordance with said revised threshold value.

5. The method of claim **4** wherein said step of revised determining said threshold value in accordance with said summed signal strengths, comprises the steps of:

multiplying said summed signal strengths by a predetermined scaling value; and

adding a predetermine value to said product.

6. A method for determining the base stations to transmit to a remote station at said remote station in which a plurality of base stations comprising an Active Set of base stations transmit to said remote station and wherein a second set of base stations which are not members of said Active Set comprise a Candidate Set of base stations, said method comprising the steps of:

aggregating signal energies of said Active Set of base stations;

generating a threshold value in accordance with said aggregated signal energies of said base station members of said Active Set;

comparing signal energy of a base station of said Candidate Set of base stations with said threshold; and

adding said base station of said Candidate Set of base stations to said Active Set of base stations when said signal energy of a base station of said Candidate Set of base stations exceeds said threshold.

7. The method of claim **6** further comprising the steps of:

determining membership of said Candidate Set by comparing the received signal energy from a predetermined set of base stations with a predetermined threshold.

8. The method of claim **6** further comprising the steps of:

sorting members of said Candidate Set in accordance with the corresponding strength of the received signal energy.

9. The method of claim **6** further comprising the steps of:

comparing the received signal strengths of a member of said Active Set against a threshold determined in accordance with the aggregate energy of the received energy of signals from base stations in the Active Set; and

removing a member from said Active Set when said received signal strength of said member is less than said threshold.

10. The method of claim **8** wherein said step of removing said member from the Active set is performed at said member has remained below said threshold for a predetermined time interval.

11. The method of claim **8** further comprising the step of transmitting a pilot strength measurement message indicating for each base station in said Candidate Set and said Active Set whether to keep said member in said Active Set.

12. An apparatus for selecting base stations to communicate with a remote station comprising:

means for computing a threshold value in accordance with a combination of measurements of signal energies from base stations capable of communicating with said remote station, wherein said combination of signal energy measurements from base stations capable of communicating with said remote station comprises the sum of pilot energy values of pilot with greater received energy than a first base station;

means for comparing a signal energy measurement of said first base station with said threshold value; and

means for selecting said first base station when said signal energy measurement of said first base station exceeds said threshold value.

13. The apparatus of claim 12 wherein said means for computing a threshold value is further for performing a linear operation upon said combination of signal energy measurements from base stations capable of communicating with said remote station.

14. In a wireless communications system wherein a first base station transmits a first pilot signal and a first traffic signal, and a second base station transmits a second pilot signal and a second traffic signal, and a remote station receives said first pilot signal and said first traffic signal, an apparatus for determining whether to add a third base station to an Active Set of said remote station, comprising:

means for demodulating said first pilot signal;

means for measuring the energy of said demodulated first pilot signal;

means for generating a threshold in accordance with said demodulated first pilot signal energy;

means for demodulating said second pilot signal;

means for measuring the energy of said demodulated second pilot signal;

means for comparing said demodulated second pilot signal energy with said threshold;

means for adding said second base station to said Active Set when said demodulated second pilot signal energy exceeds said threshold;

means for generating a revised threshold in accordance with a combination of said demodulated first pilot signal energy and said demodulated second pilot signal energy;

means for demodulating a third pilot signal from said third base station;

means for measuring the energy of said demodulated third pilot signal;

means for comparing said demodulated third pilot signal energy with said revised threshold; and

means for adding said third base station to said Active Set when said demodulated third pilot signal energy exceeds said revised threshold.

15. In a wireless communications system in which a plurality of base stations are in communication with a base station controller, an apparatus for determining an Active Set of base stations to communicate with a remote station at said base station controller, comprising:

means for receiving a signal strength measurement message indicative of the signal strengths associated with each of said plurality of base stations as measured at said remote station;

means for selecting a first base station as a member of said Active Set of base stations;

means for calculating a threshold value in accordance with a signal strength of said selected first base station;

means for selecting a second base station as a member of said Active Set of base stations in accordance with said threshold value;

means for summing the signal strengths associated with each of said two selected base stations; and

means for determining a revised threshold value in accordance with said summed signal strengths and;

means for determining remaining members of said Active Set in accordance with said revised threshold value.

16. The apparatus of claim 15 wherein said means for determining said revised threshold value in accordance with said summed signal strengths is further for multiplying said summed signal strengths by a predetermined scaling value and adding a predetermined value to said product.

17. An apparatus for determining the base stations to transmit to a remote station at said remote station in which a plurality of base stations comprising an Active Set of base stations transmit to said remote station and wherein a second set of base stations which are not members of said Active Set comprise a Candidate Set of base stations, said apparatus comprising:

means for aggregating signal energies of said Active Set of base stations;

means for generating a threshold value in accordance with said aggregated signal energies of said base station members of said Active Set;

means for comparing signal energy of a base station of said Candidate Set of base stations with said threshold; and

means for adding said base station of said Candidate Set of base stations to said Active Set of base stations when said signal energy of a base station of said Candidate Set of base stations exceeds said threshold.

18. The apparatus of claim 17 further comprising:

means for determining membership of said Candidate Set by comparing the received signal energy from a predetermined set of base stations with a predetermined threshold.

19. The apparatus of claim 17 further comprising;

means for sorting members of said Candidate Set in accordance with the corresponding strength of the received signal energy.

20. The apparatus of claim 17 further comprising:

means for comparing the received signal strengths of a member of said Active Set against a threshold determined in accordance with the aggregate energy of the received energy of signals from base stations in the Active Set; and

means for removing a member from said Active Set when said received signal strength of said member is less than said threshold.

21. The apparatus of claim 19 wherein said means for removing said member from the Active set removes said member if said member has remained below said threshold for a predetermined time interval.

22. The apparatus of claim 19 further comprising means for transmitting a pilot strength measurement message indicating for each base station in said Candidate Set and said Active Set whether to keep said member in said Active Set.

23. A method for generating a dynamic threshold used for revising a base station set, comprising:

(a) forming a combined energy value using energy values associated with members of the base station set;

(b) using the combined energy value to produce the dynamic threshold;

(c) comparing a received pilot energy value to the dynamic threshold to determine whether to update the base station set with a base station associated with the received pilot energy value;

(d) if the received pilot energy value exceeds the dynamic threshold, then incorporating the received pilot energy value into the combined energy value, whereupon the new combined energy value is used to produce a new dynamic threshold; and

(e) repeating steps (c)–(d) for each received pilot energy value.

24. An apparatus for generating a dynamic threshold used for revising a base station set, comprising:

means for forming a combined energy value using energy values associated with members of the base station set;

means for using the combined energy value to produce the dynamic threshold;

means for comparing a received pilot energy value to the dynamic threshold to determine whether to update the base station set with a base station associated with the received pilot energy value; and

means for incorporating the received pilot energy value into the combined energy value if the received pilot energy value exceeds the dynamic threshold, whereupon the new combined energy value is used to produce a new dynamic threshold.

25. An apparatus for facilitating handoff of a mobile station within a wireless communication system, comprising a processor configured to:

sort a plurality of pilot energy values in a first pilot set;

sum a portion of the plurality of pilot energy values in the sorted first pilot set to determine a combined pilot energy sum;

determine a threshold value in accordance with the combined pilot energy sum;

select a pilot energy value that is not a member of the summed portion of the plurality of pilot energy values;

compare the selected pilot energy value to the threshold value;

decide that the portion of the plurality of pilot energy values forming the combined pilot energy sum does not need revision if the selected pilot energy value does not exceed the threshold value; and

decide that the portion of the plurality of pilot energy values forming the combined pilot energy sum needs *revision if the selected pilot energy value exceeds the threshold value.*

26. The apparatus of claim 25, further comprising a message generator that is controlled by the processor to transmit a message to a base station controller if the processor decides that the portion of the plurality of pilot energy values forming the combined pilot energy sum needs revision, wherein the message carries information regarding the plurality of pilot energy values.

27. The apparatus of claim 26, wherein the selected pilot energy value is selected from a Candidate Set (CS).

28. The apparatus of claim 27, wherein the first pilot set is an Active Set (AS).

29. The apparatus of claim 28, wherein the processor is configured to sum the portion of the plurality of pilot energy values in the sorted Active Set by summing all members of the Active Set.

30. The apparatus of 29, wherein the plurality of AS pilot energy values are sorted from the weakest to the strongest.

31. The apparatus of claim 30, wherein processor is further configured to sort a plurality of Candidate Set pilot energy values from the strongest to the weakest before selecting the pilot energy value from the Candidate Set, wherein the strongest pilot energy value is selected from the Candidate Set.

32. The apparatus of claim 31, wherein the processor is further configured to:

select an AS pilot energy value from the sorted AS;

sum all pilot energy values of the Active Set stronger than the selected AS pilot energy value to form a combined AS pilot energy sum;

determine an AS threshold value in accordance with the combined AS pilot energy sum;

compare the selected AS pilot energy value to the AS threshold value;

reset a drop timer if the selected AS pilot energy value exceeds the AS threshold value and store the selected AS pilot energy value and all pilot energy values of the AS stronger than the selected AS pilot energy value; and

advance a drop timer for the selected AS pilot energy value if the selected AS pilot energy value does not exceed the AS threshold value.

33. The apparatus of claim 32, further comprising a message generator communicatively coupled to the processor, wherein, then the processor caused the message generator to send a pilot strength measurement message to a base station controller if the drop timer has expired.

34. The apparatus of claim 33, wherein if the drop timer has not expired, then the processor is further configured to select a next AS pilot energy value from the sorted Active Set, sum all pilot energy values of the Active Set stronger than the next selected AS pilot energy value, determine a new AS threshold value, compare the next selected AS pilot energy value to the new AS threshold value, and repeat the above steps until the drop timer is expired.

35. The apparatus of claim 34, wherein the processor is located within the mobile station.

36. The apparatus of claim 34, wherein the threshold value is determined in accordance with the following relationship:

*T=SOFT_SLOPE*COMBINED_PILOT+SOFT_ADD_INTERCEPT,*

wherein COMBINED_PILOT represents the combined pilot energy sum, and SOFT_SLOPE and SOFT_ADD_INTERCEPT are system parameters.

37. The apparatus of claim 36, wherein the AS threshold value is determined in accordance with the following relationship:

*T=SOFT_SLOPE*COMBINED_PILOT+SOFT_DROP_INTERCEPT,*

wherein COMBINED_PILOT represents the sum of all pilot energy values of the Active set stronger than the selected AS pilot energy value, and SOFT_SLOPE and SOFT_DROP_INTERCEPT are system parameters.

38. The apparatus of claim 25, wherein if the processor decides that the portion of the plurality of pilot energy values forming the combined pilot energy sum needs revision, then the processor is further configured to:

include the selected pilot energy value within the combined pilot energy sum to form a revised combined pilot energy sum;

determine a revised threshold value in accordance with the revised combined pilot energy sum; and

select the next pilot energy value that is not a member of the summed portion of the plurality of pilot energy values, wherein the above steps repeat until a selected pilot energy value does not exceed a revised threshold value.

39. The apparatus of claim 38, wherein the summed portion of the plurality of pilot energy values is designated as an Active Set (AS).

40. The apparatus of claim 39, wherein the processor sorts the plurality of pilot energy values from the strongest pilot energy value of the first pilot set to the weakest pilot energy value of the first pilot set.

41. The apparatus of claim 40, wherein the processor is located within the mobile station.

42. The apparatus of claim 41, wherein the processor causes the message generator to send a plot strength measurement message to a base station controller if the Active Set is different from a current Active Set.

43. The apparatus of claim 40, wherein the processor is located within a base station controller.

44. The apparatus of claim 43, wherein the processor is further configured to remove from the Active Set a pilot energy value associated with a base station with a high capacity load condition.

45. The apparatus of claim 43, wherein the processor is further configured to weigh the selected pilot energy value if the selected pilot energy value is associated with a base station with a high capacity load condition.

46. The apparatus of claim 38, wherein determining the threshold value is performed in accordance to a linear operation.

47. The apparatus of claim 46, wherein the threshold value is determined in accordance with the following relationship:

*T=SOFT_SLOPE*COMBINED_PILOT+SOFT_INTERCEPT,*

wherein COMBINED_PILOT represents the combined pilot energy sum, and SOFT_SLOPE and SOFT_INTERCEPT are system parameters.

48. The apparatus of claim 47, wherein the SOFT_SLOPE and SOFT_INTERCEPT parameters are preprogrammed within the mobile station.

49. The apparatus of claim 48, wherein the SOFT_SLOPE parameter is set to 2.25 and SOFT_INTERCEPT parameter is set to 3.0.

50. The apparatus of claim 47, wherein the SOFT_SLOPE and SOFT_INTERCEPT parameters are transmitted from a base station controller to the mobile station.

51. The apparatus of claim 47, wherein the selected pilot energy value is selected from a Candidate Set (CS).

52. The apparatus of claim 51, wherein the first pilot set is an Active Set (AS).

53. The apparatus of claim 52, wherein summing the portion of the plurality of pilot energy values in the sorted Active Set sums all members of the Active Set.

54. The apparatus of claim 53, wherein the plurality of AS pilot energy values are sorted from the weakest to the strongest.

55. The apparatus of claim 54, wherein processor is further configured to sort a plurality of Candidate Set pilot energy values from the strongest to the weakest before selecting the pilot energy value from the Candidate Set, wherein selecting occurs at the strongest pilot energy value.

56. The apparatus of claim 55, wherein the processor is further configured to:

select an AS pilot energy value from the sorted AS;

sum all pilot energy values of the Active Set stronger than the selected AS pilot energy value to form a combined AS pilot energy sum;

determine an AS threshold value in accordance with the combined AS pilot energy sum;

compare the selected AS pilot energy value to the AS threshold value;

reset a drop timer if the selected AS pilot energy value exceeds the AS threshold value and store the selected AS pilot energy value and all pilot energy values of the AS stronger than the selected AS pilot energy value; and

advance a drop timer for the selected AS pilot energy value if the selected AS pilot energy value does not exceed the AS threshold value.

57. The apparatus of claim 56, wherein if the drop timer has expired, then the processor removes the selected AS pilot energy value from the AS.

58. The apparatus of claim 57, wherein if the drop timer has not expired, then the processor is further configured to:

select a next AS pilot energy value from the sorted Active Set;

sum all pilot energy values of the Active Set stronger than the next selected AS pilot energy value;

determine a new AS threshold value;

compare the next selected AS pilot energy value to the new AS threshold value; and

repeat the above steps until the drop timer is expired.

59. The apparatus of claim 58, wherein the processor is located within the mobile station.

60. The apparatus of claim 59, further comprising a message generator that is controlled by the processor to transmit a message to a base station controller if the processor decides the Active Set is different from a current Active Set.

61. The apparatus of claim 59, further comprising a message generator that is controlled by the processor to transmit a message to a base station controller if the processor decides the Candidate Set is different from a current Candidate Set.

62. The apparatus of claim 58, wherein the processor is located within a base station controller.

63. The apparatus of claim 62, wherein the processor is further configured to remove from the Active Set a pilot energy value associated with a base station with a high capacity load condition.

64. The apparatus of claim 62, wherein the processor is further configured to weigh the selected AS pilot energy value if the selected AS pilot energy value is associated with a base station with a high capacity load condition.

65. The apparatus of claim 38, wherein determining the threshold value is performed in accordance to a linear operation.

66. The apparatus of claim 65, wherein the threshold value is determined in accordance with the following relationship:

*T=SOFT_SLOPE*COMBINED_PILOT+SOFT_INTERCEPT,*

wherein COMBINED_PILOT represents the combined pilot energy sum, and SOFT_SLOPE and SOFT_INTERCEPT are system parameters.

67. The apparatus of claim 66, wherein the SOFT_SLOPE and SOFT_INTERCEPT parameters are preprogrammed within the mobile station.

68. The apparatus of claim 67, wherein the SOFT_SLOPE parameter is set to 2.25 and SOFT_INTERCEPT parameter is set to 3.0.

69. The apparatus of claim 66, wherein the SOFT_SLOPE and SOFT_INTERCEPT parameters are transmitted from a base station controller to the mobile station.

70. The apparatus of claim 66, wherein the AS threshold value is determined in accordance with the following relationship:

*T=SOFT_SLOPE*COMBINED_PILOT+SOFT_INTERCEPT,*

wherein COMBINED_PILOT represents the sum of all pilot energy values of the Active set stronger than the selected AS pilot energy value, and SOFT_SLOPE and SOFT_INTERCEPT are system parameters.

71. An apparatus for shortening a search through adjacent pilot sets that are used for facilitating handoff of a mobile station within a wireless communication system, comprising:

a processor configured to execute a set of instructions for:

sorting a first pilot set from a stronger first pilot energy value to a weakest first pilot energy value;

selecting a first pilot energy value from the sorted first pilot set;

comparing the selected first pilot energy value to a first threshold value;

if the selected first pilot energy value exceeds the first threshold value, then reallocating the selected first pilot energy value to a second pilot set and selecting the next first pilot energy value from the sorted first pilot set, wherein the above steps repeat until a selected first pilot energy value does not exceed the first threshold value;

if the selected first pilot energy value does not exceed the first threshold value, then:

sorting a second pilot set from a weakest second pilot energy value to a strongest second pilot energy value;

selecting a second pilot energy value from the sorted second pilot set; and

comparing the selected second pilot energy value to a second threshold value.

72. The apparatus of claim 71, wherein the set of instructions is further for:

if the selected second pilot energy value exceeds the second threshold value, then resetting a drop timer and finishing the search; and

if the selected second pilot energy value does not exceed the second threshold value, then advancing a drop *timer, selecting a next second pilot energy value from the sorted second pilot set, and comparing the next selected second pilot energy to the second threshold value, wherein the above steps repeat until the drop timer expires.*

73. The apparatus of claim 72, wherein the set of instructions is further for:

if the drop time expires, then removing the selected second pilot energy value from the second pilot set.

74. The apparatus of claim 73, wherein the first pilot set is a Neighbor Set.

75. The apparatus of claim 74, wherein the second pilot set is a Candidate Set.

76. The apparatus of claim 72, wherein the processor is located within the mobile station.

77. The apparatus of claim 72, wherein the processor is located within a base station controller.

78. An apparatus for facilitating handoff of a mobile station within a wireless communication system by timely updating pilot energies from base stations, comprising:

a processor for summing a portion of the plurality of pilot energy values in a first pilot set to determine a combined pilot energy sum, and for determining a threshold value in accordance with the combined pilot energy sum, wherein the threshold value is updated to incorporate pilot energy values that exceed the threshold value and the first pilot set is revised to incorporate base stations associated with the pilot energy values that exceed the threshold value; and

a generator for generating a message carrying first pilot set information.

79. The apparatus of claim 78, wherein the processor is further for sorting a plurality of pilot energy values in the first pilot set.

80. The apparatus of claim 78, wherein the processor is further for:

selecting a pilot energy value that is not a member of the summed portion of the plurality of pilot energy values; and

comparing the selected pilot energy value to the threshold value to decide whether to revise the first pilot set.

81. The apparatus of claim 80, wherein if the compared pilot energy value does not exceed the threshold value, then deciding that the portion of the plurality of pilot energy values forming the combined pilot energy sum need not include the compared pilot energy value so that the first pilot set need not be revised.

82. The apparatus of claim 80, wherein if the compared pilot energy value exceeds the threshold value, then deciding that the portion of the plurality of pilot energy values forming the combined pilot energy sum needs to include the compared pilot energy value so that the first pilot set needs to be revised.

83. In a wireless communication system wherein a remote station is in communication with a plurality of base stations, a method for selecting an additional base station for communication with the remote station comprising:

sorting a plurality of signal energies according to signal strength, wherein each of the plurality of signal energies correspond with one of the plurality of base stations;

computing a threshold value from a subset of the plurality of signal energies, wherein the subset of the plurality of signal energies is determined by the step of sorting the plurality of signal energies;

comparing a signal energy measurement of the additional base station with said threshold value; and

selecting the additional base station when the signal energy measurement of the additional base station exceeds the threshold value.

84. The method of claim 83 wherein computing a threshold value comprises performing a linear operation upon the plurality of signal energies.

85. The method of claim 84 wherein said linear operation comprises:

multiplying said plurality of signal energies by a first variable; and

summing a second variable with the product of said multiplication.

86. The method of claim 85 wherein said first variable has a value of 2.25.

87. The method of claim 85 wherein said second variable has a value of 3.0.

88. The method of claim 83, the method further comprising transmitting a message indicative of the signal energy measurement of the additional base station from said remote station.

89. The method of claim 83, the method further comprising removing a weak base station from the plurality of base stations when the signal energy measurement of the weak base station is below said threshold value.

90. In a wireless communication system wherein a remote station is in communication with at least one base station, an apparatus for maintaining communications between the remote station and the at least one base station in accordance with signal strength, comprising:

means for receiving pilot signals from base stations;

means for:

sorting a plurality of signal energies according to signal strength, wherein each of the plurality of signal energies correspond with one of the plurality of base stations;

computing a threshold value from a subset of the plurality of signal energies, wherein the subset of the plurality of signal energies is determined by the step of sorting the plurality of signal energies;

comparing a signal energy measurement of the additional base station with said threshold value; and

selecting the additional base station when the signal energy measurement of the additional base station exceeds the threshold value, wherein the processor means is communicatively connected to the receiver means.

91. A method for facilitating handoff of a mobile station within a wireless communication system, comprising:

sorting a plurality of pilot energy values in a first pilot set;

summing a portion of the plurality of pilot energy values in the sorted first pilot set to determine a combined pilot energy sum;

determining a threshold value in accordance with the combined pilot energy sum;

selecting a pilot energy value that is not a member of the summed portion of the plurality of pilot energy values;

comparing the selected pilot energy value to the threshold value;

deciding that the portion of the plurality of pilot energy values forming the combined pilot energy sum does not need revision if the selected pilot energy value does not exceed the threshold value; and

deciding that the portion of the plurality of pilot energy values forming the combined pilot energy sum needs revision if the selected pilot energy value exceeds the threshold value.

92. The method of claim 91, wherein deciding that the portion of the plurality of pilot energy values forming the combined pilot energy sum needs revision comprises:

including the selected pilot energy value within the combined pilot energy sum to form a revised combined pilot energy sum;

determining a revised threshold value in accordance with the revised combined pilot energy sum; and

selecting the next pilot energy value that is not a member of the summed portion of the plurality of pilot energy values, wherein the above steps repeat until a selected pilot energy value does not exceed a revised threshold value.

93. A method for shortening a search through adjacent pilot sets that are used for facilitating handoff of a mobile station within a wireless communication system, comprising:

sorting a first pilot set from a strongest first pilot energy value to a weakest first pilot energy value;

selecting a first pilot energy value from the sorted first pilot set;

comparing the selected first pilot energy value to a first threshold value; and

if the selected first pilot energy value exceeds the first threshold value, then reallocating the selected first pilot energy value to a second pilot set and selecting the next first pilot energy value from the sorted first pilot set, wherein the above steps repeat until a selected first pilot energy value does not exceed the first threshold value; or

if the selected first pilot energy value does not exceed the first threshold value, then:

sorting a second pilot set from a weakest second pilot energy value to a strongest second pilot energy value;

selecting a second pilot energy value from the sorted second pilot set; and

comparing the selected second pilot energy value to a second threshold value.

94. The method of claim 93, further comprising:

if the selected second pilot energy value exceeds the second threshold value, then resetting a drop timer and finishing the search; and

if the selected second pilot energy value does not exceed the second threshold value, then advancing a drop timer, selecting a next second pilot energy value from the sorted second pilot set, and comparing the next selected second pilot energy to the second threshold value, wherein the above steps repeat until the drop timer expires.

* * * * *