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(54) **BASE STATION USING GLOBAL CHANNEL POWER CONTROL**

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(63) Continuation of application No. 10/361,669, filed on Feb. 10, 2003, now Pat. No. 7,085,531, which is a continuation of application No. 10/176,276, filed on Jun. 20, 2002, now Pat. No. 6,542,719, which is a continuation of application No. 10/046,025, filed on Oct. 29, 2001, now Pat. No. 6,456,828, which is a continuation of application No. 09/904,021, filed on

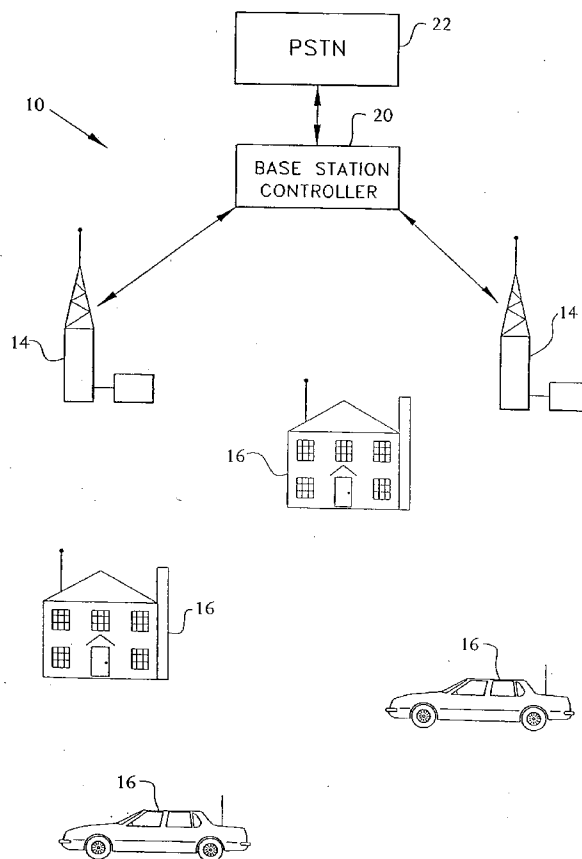
Jul. 12, 2001, now Pat. No. 6,360,079, which is a continuation of application No. 09/665,865, filed on Sep. 20, 2000, now Pat. No. 6,341,215, which is a continuation of application No. 09/196,808, filed on Nov. 20, 1998, now Pat. No. 6,181,919, which is a continuation of application No. 08/797,989, filed on Feb. 12, 1997, now Pat. No. 5,842,114.

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(57) **ABSTRACT**

A wireless spread spectrum base station has a plurality of modems. The modems produce at least one baseband channel signal and a baseband reference signal. At least one forward power controller controls a power level of the at least one baseband channel signal. A baseband signal combiner combines the at least one baseband channel and baseband reference signals. A radio frequency transmitter modulates to radio frequency and transmits the combined signal. A reference power control processor determines a desired transmit power level of the baseband reference signal to the desired transmit power level.



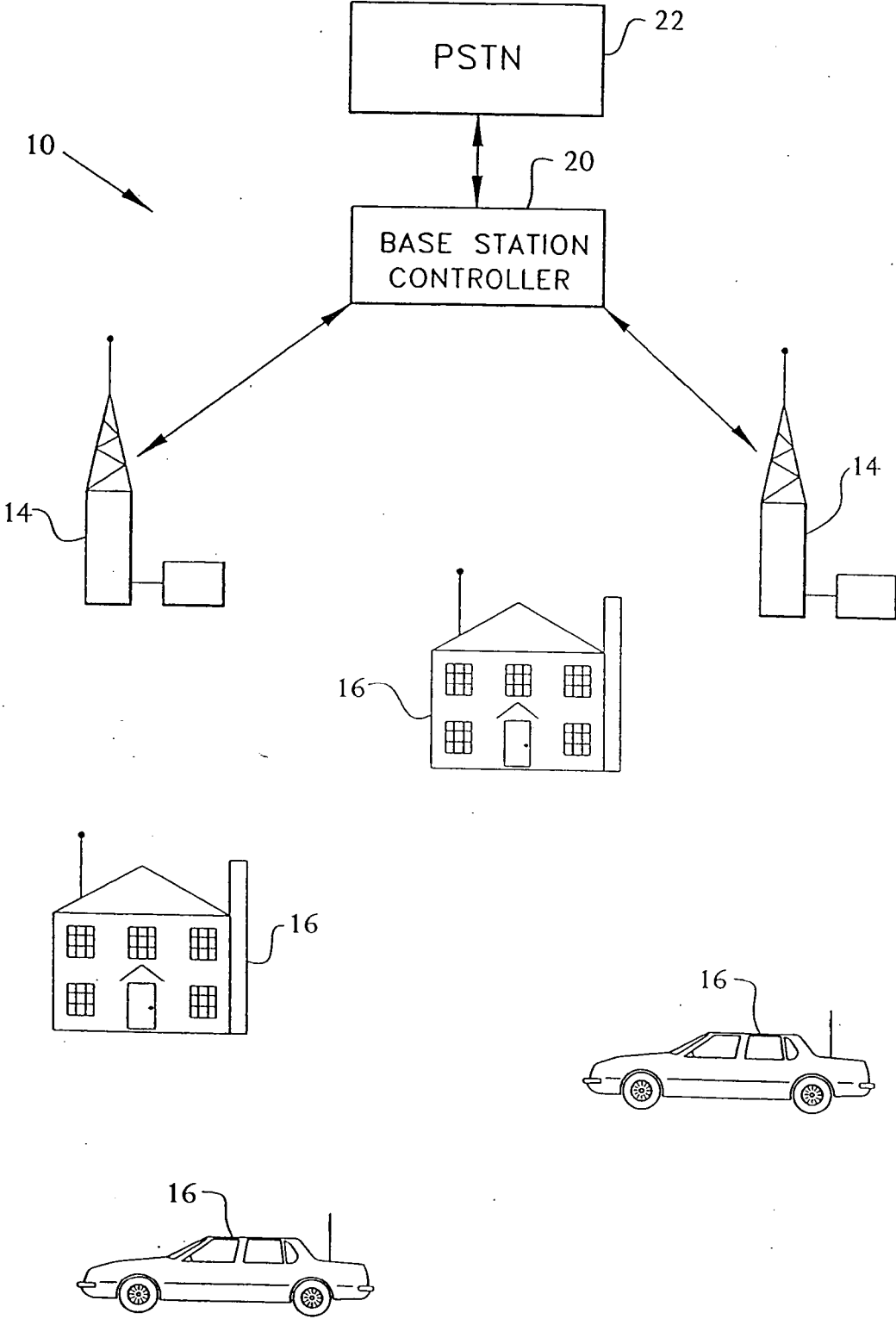


FIG. 1

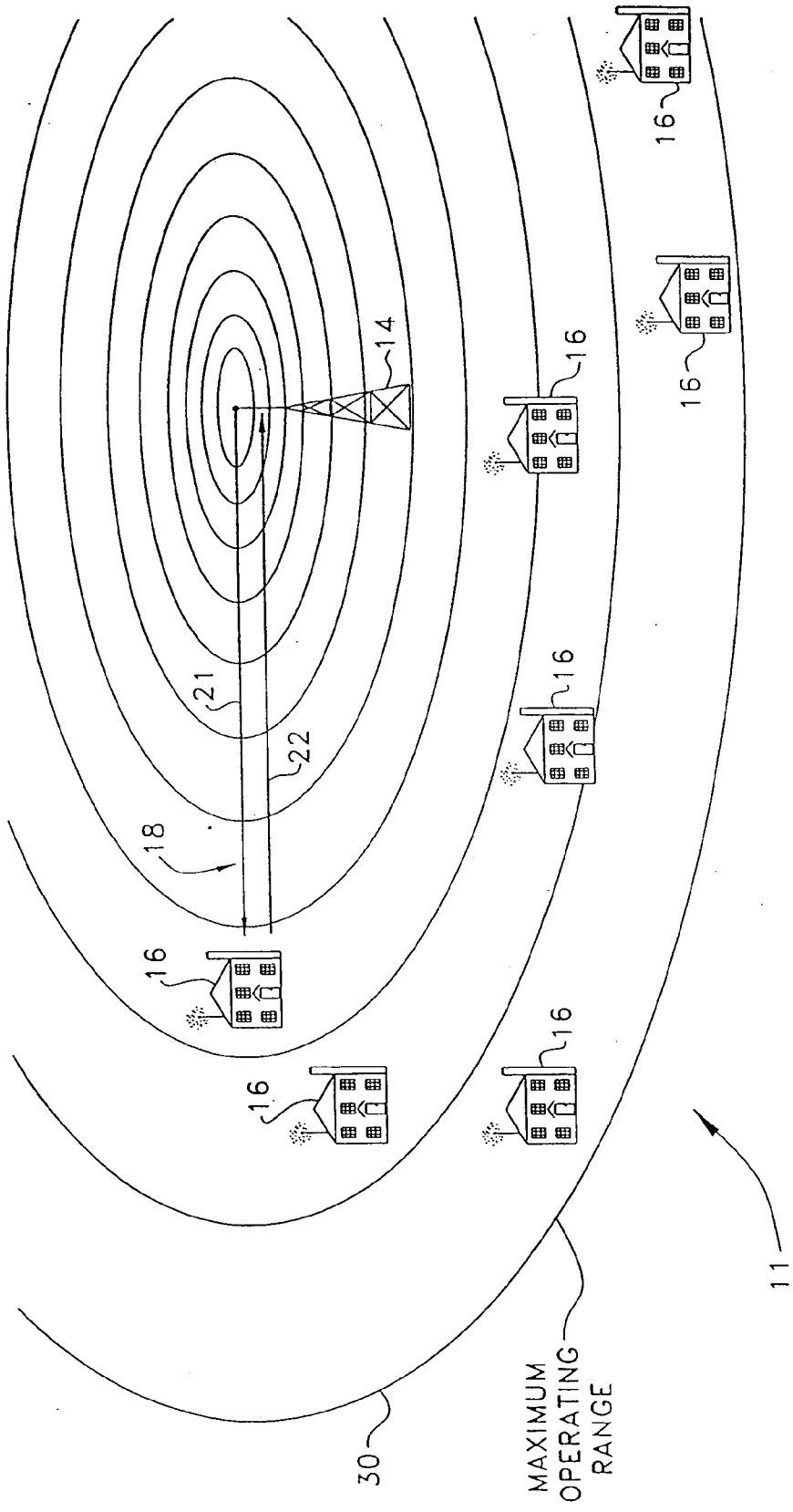


FIG. 2

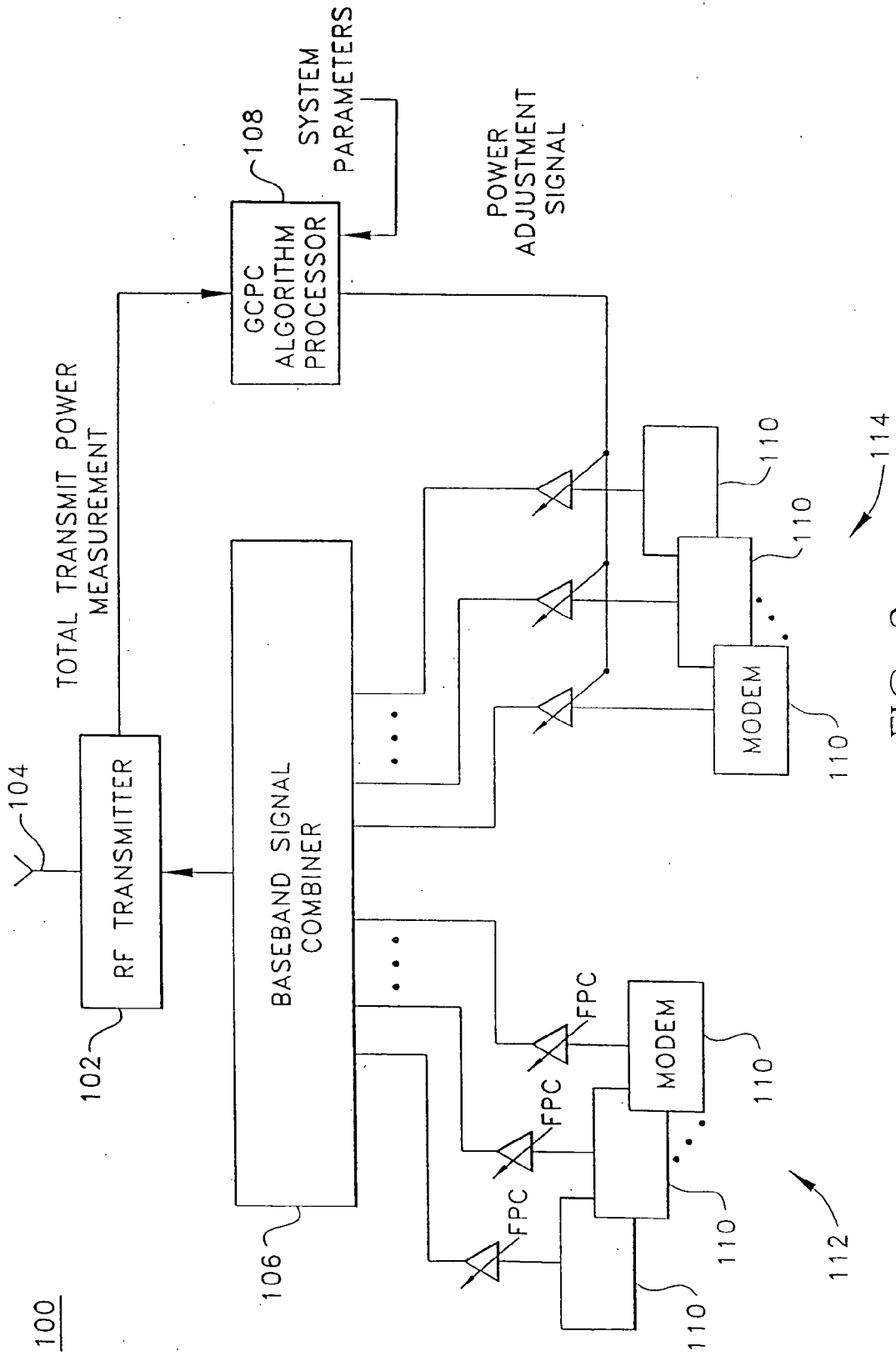
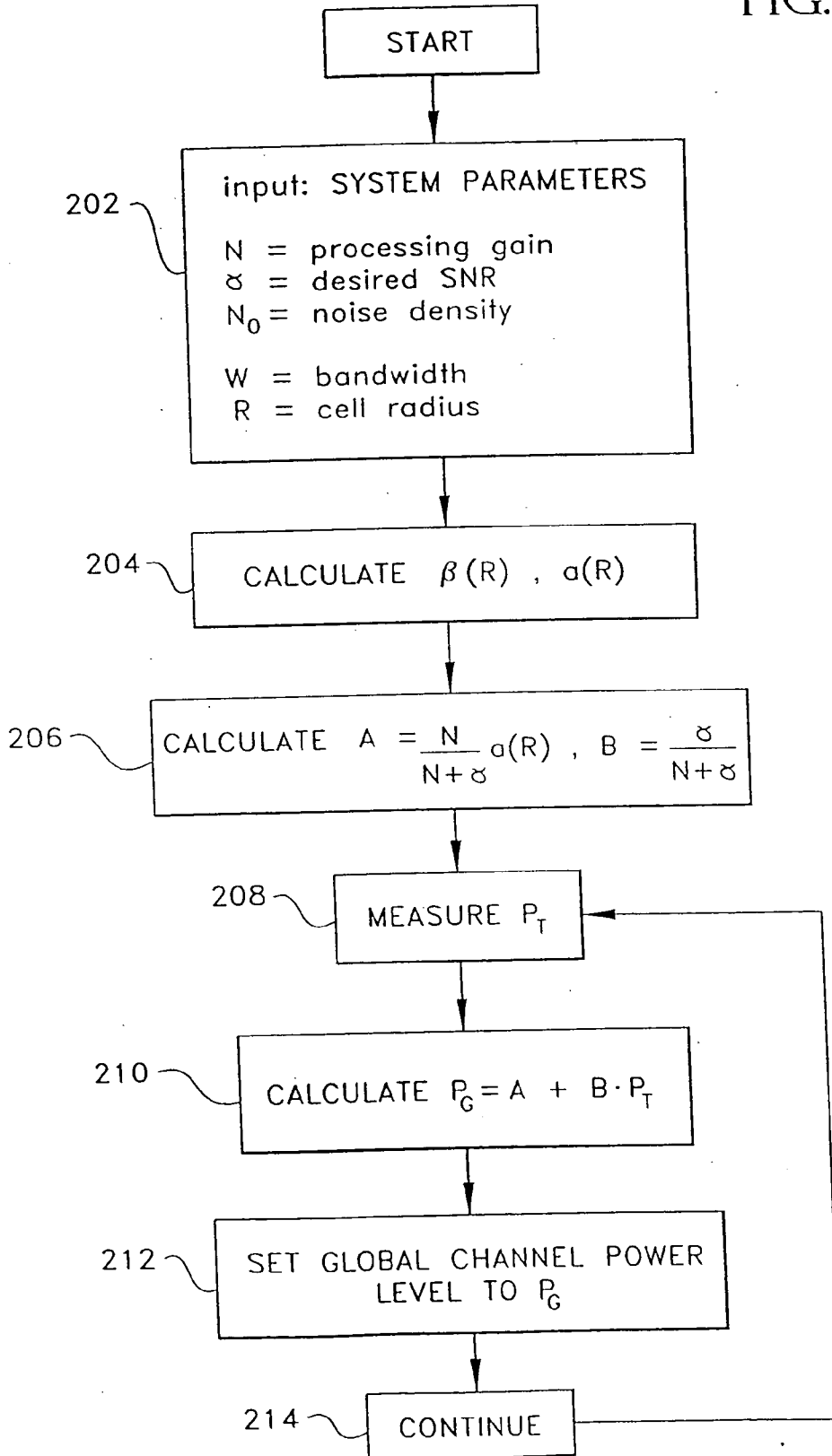


FIG. 3

FIG. 4



BASE STATION USING GLOBAL CHANNEL POWER CONTROL

CROSS REFERENCE TO RELATED APPLICATION(S)

[0001] This application is a continuation of U.S. patent application Ser. No. 10/361,669 filed on Feb. 10, 2003, which is a continuation of U.S. patent application Ser. No. 10/176,276, filed on Jun. 20, 2002, which issued on Apr. 1, 2003 as U.S. Pat. No. 6,542,719, which is a continuation of U.S. patent application Ser. No. 10/046,025, filed on Oct. 29, 2001, which issued on Sep. 24, 2002 as U.S. Pat. No. 6,456,828, which is a continuation of U.S. patent application Ser. No. 09/904,021, filed on Jul. 12, 2001, which issued on Mar. 19, 2002 as U.S. Pat. No. 6,360,079, which is a continuation of U.S. patent application Ser. No. 09/665,865, filed on Sep. 20, 2000, which issued on Jan. 22, 2002 as U.S. Pat. No. 6,341,215, which is a continuation of U.S. patent application Ser. No. 09/196,808, filed on Nov. 20, 1998, which issued on Jan. 30, 2001 as U.S. Pat. No. 6,181,919, which is a continuation of U.S. application Ser. No. 08/797,989, filed on Feb. 12, 1997, which issued on Nov. 24, 1998 as U.S. Pat. No. 5,842,114, which is/are incorporated by reference as if fully set forth.

BACKGROUND

[0002] 1. Field of the Invention

[0003] The present invention relates generally to wireless local loop and cellular communication systems. More particularly, the present invention relates to a wireless communication system which dynamically adjusts the power of signals transmitted over reference channels from a base station to minimize power spillover to adjacent communication cells.

[0004] 2. Description of the Related Art

[0005] Wireless communication systems have rapidly become a viable alternative to wired systems due to their inherent advantages. Wireless systems enable subscribers to freely move throughout the operating range of a service provider and even into the territory of other service providers while using the same communication hardware. Wireless communication systems are also utilized for applications where wired systems are impractical, and have become an economically viable alternative to replacing aging telephone lines and outdated telephone equipment.

[0006] One of the drawbacks with wireless communication systems is the limited amount of available RF bandwidth. There is a constant desire to improve the efficiency of these systems in order to increase system capacity and meet the rising consumer demand. A factor that degrades the overall capacity of wireless communication systems is signal power spillover between adjacent cells or base stations. This occurs when the power of signals transmitted by a base station in a particular cell exceeds the boundary of that cell, otherwise known as the operating range. The spillover becomes interference to adjacent cells and degrades the efficiency of the system. Accordingly, minimizing spillover is one of the most important issues in wireless communications system design.

[0007] Forward power control (FPC) is used to minimize spillover by adjusting the power level of signals transmitted

from the base station to subscriber units on assigned channels. The FPC operates in a closed loop wherein each subscriber unit continuously measures its received signal-to-noise ratio and transmits an indication back to the base station of whether the base station should increase or decrease the transmit power to that subscriber unit. The closed loop algorithm assists in maintaining the transmit power level from the base station at a minimum acceptable level, thereby minimizing spillover to adjacent cells.

[0008] FPC, however, cannot adjust the power level for reference channels such as the pilot signal, broadcast channel or paging channel. Since there is no closed loop algorithm that operates on these channels, the reference channel transmit power level for the worst case scenario is typically used. The power level is generally more than what is required for most subscriber units, resulting in spillover to adjacent cells.

[0009] There have been prior attempts to overcome the problem of spillover. U.S. Pat. No. 5,267,262 (Wheatley, III) discloses a power control system for use with a CDMA cellular mobile telephone system including a network of base stations, each of which communicates with a plurality of subscriber units. Each base station transmits a pilot signal which is used by the mobile units to estimate the propagation loss of the pilot signals. The combined power of all base station transmitted signals as received at a mobile unit is also measured. This power level sum is used by the mobile units to reduce transmitter power to the minimum power required. Each base station measures the strength of a signal received from a mobile unit and compares this signal strength level to a desired signal strength level for that particular mobile unit. A power adjustment command is generated and sent to the mobile unit which adjusts its power accordingly. The transmit power of the base station may also be increased or decreased depending upon the average noise conditions of the cell. For example, a base station may be positioned in an unusually noisy location and may be permitted to use a higher than normal transmit power level. However, this is not performed dynamically, nor is the power correction based upon the total transmit power of the base station.

[0010] Accordingly, there exists a need for an effective method for controlling the power level of reference channels transmitted from a base station.

SUMMARY

[0011] A base station for use in a wireless spread spectrum communication system produces at least one channel signal and a reference signal. The at least one channel and reference signals are combined. The combined signal is transmitted. A desired transmit power level of the reference signal is determined using a transmit power level of the combined signal. A transmit power level of the reference signal is adjusted using the desired transmit power level.

BRIEF DESCRIPTION OF THE DRAWING(S)

[0012] **FIG. 1** is a communication network embodying the present invention;

[0013] **FIG. 2** is the propagation of signals between a base station and a plurality of subscriber units;

[0014] **FIG. 3** is a base station made in accordance with the present invention; and

[0015] FIG. 4 is a flow diagram of the method of dynamically controlling the transmit power of reference channels in accordance with the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT(S)

[0016] The preferred embodiment will be described with reference to the drawing figures wherein like numerals represent like elements throughout.

[0017] A communication network 10 embodying the present invention is shown in FIG. 1. The communication network 10 generally comprises one or more base stations 14, each of which is in wireless communication with a plurality of fixed or mobile subscriber units 16. Each subscriber unit 16 communicates with either the closest base station 14 or the base station 14 which provides the strongest communication signal. The base stations 14 also communicate with a base station controller 20 which coordinates communications among base stations 14 and between base stations 14 and the subscriber units 16. The communication network 10 may optionally be connected to a public switched telephone network (PSTN) 22, whereupon the base station controller 20 also coordinates communication between the base stations 14 and the PSTN 22. Preferably, each base station 14 is coupled with the base station controller 20 via a wireless link, although a land line may also be provided. A land line is particularly applicable when a base station 14 is in close proximity to the base station controller 20.

[0018] The base station controller 20 performs several functions. Primarily, the base station controller 20 provides all of the operation, administration and maintenance (OA&M) signaling associated with establishing and maintaining the communications between the subscriber units 16, the base stations 14 and the base station controller 20. The base station controller 20 also provides an interface between the wireless communication system 10 and the PSTN 22. This interface includes multiplexing and demultiplexing of the communication signals that enter and exit the system 10 via the base station controller 20. Although the wireless communication system 10 is shown as employing antennas to transmit RF signals, one skilled in the art should recognize that communications may be accomplished via microwave or satellite uplinks. Additionally, the functions of a base station 14 may be combined with the base station controller 20 to form a master base station. The physical location of the base station controller 20 is not central to the present invention.

[0019] Referring to FIG. 2, the propagation of certain signals in the establishment of a communication channel 18 between a base station 14 and a plurality of subscriber units 16 is shown. Forward signals 21 are transmitted from the base station 14 to a subscriber unit 16. Reverse signals 22 are transmitted from the subscriber unit 16 to the base station 14. All subscriber units 16 located within the maximum operating range 30 of the cell 11 are serviced by that base station 14.

[0020] Referring to FIG. 3, a base station 100 made in accordance with the present invention is shown. The base station 100 includes an RF transmitter 102, an antenna 104, a baseband signal combiner 106 and a reference channel power control (GCPC) algorithm processor 108. The base

station 100 also includes a plurality of modems 110, one for each channel, for generating a plurality of assigned channels 112 and a plurality of reference channels 114. Each modem 110 includes associated code generators, spreaders and other equipment for defining a communication channel as is well known by those skilled in the art. Communications over assigned and reference channels 112, 114 are combined by the combiner 106 and upconverted by the RF transmitter 102 for transmission. The power of each assigned channel 110 is individually controlled by the FPC. However, in accordance with the present invention, the power of the reference channels 114 is simultaneously and dynamically controlled by the GCPC processor 108.

[0021] The total transmit power of all channels 112, 114 is measured at the RF transmitter 102 and this measurement is input into the GCPC processor 108. As will be described in detail hereinafter, the GCPC processor 108 analyzes the total transmit power of all channels 112, 114 and calculates the desired transmit power level of the reference channels 114. Preferably, the power level is measured prior to outputting the RF signal to the antenna 104. Alternatively, the power level may be: 1) measured at the combiner 106; 2) sampled at each assigned and reference channel 112, 114 and summed; or 3) received as an RF signal just after transmission using a separate antenna (not shown) co-located with the base station antenna 104. Those skilled in the art should realize that any method for monitoring the total transmit power at the base station 100 may be employed without significantly departing from the spirit and scope of the present invention.

[0022] Dynamic control of the power of reference channels 114 is performed by using several assumptions in analyzing the total transmit power. It is assumed that the FPC for the assigned channels 112 is working ideally and the power transmitted to each subscriber unit 16 is adjusted so that all subscriber units 16 receive their signals at a particular signal-to-noise ratio. Since changing the transmit power to a particular subscriber unit 16 affects the signal-to-noise ratio seen at other subscriber units 16, the analysis of transmit power by FPC for each assigned channel 112 is preferably performed continuously. Alternatively, the analysis may be performed on a periodic basis, as appropriate, to adjust the power for each assigned channel 112.

[0023] Prior to the analysis of the total transmit power, several factors must be defined: γ denotes the signal-to-noise ratio required at a subscriber unit 16, N_0 the white noise power density, W the transmit bandwidth and N the processing gain. The propagation loss is such that if the transmit power is P , the power level P_r of a subscriber unit 16 located at distance r is:

$$P_r = P * \beta(r) \quad \text{Equation (1)}$$

[0024] Different propagation models may be utilized depending upon the size of the cell, such as a free space propagation model, a Hata model or a break-point model.

[0025] Those of skill in the art should realize that any empirical or theoretical propagation model may be used in

accordance with the teachings of the present invention. For example, the free space propagation model is used in small cells. In this model the propagation loss is:

$$\beta(r) = \frac{\alpha}{r^2} \tag{Equation (2)}$$

where

$$\alpha = \frac{\lambda^2}{(4\pi)^2} \tag{Equation (3)}$$

and λ is the wavelength of the carrier frequency. Accordingly, if the transmit power is P, the power seen at distance r is inversely proportional to the square of the distance. Thus, the power P_r seen at distance r is:

$$P_r = P * \frac{\alpha}{r^2} \tag{from Equations 1 and 2}$$

[0026] When the FPC is operating on assigned channels 112, the power transmitted P_1 from the base station 100 to a subscriber 16 that is located at a distance r_1 from the base station 100 is:

$$P_i = \frac{N}{N + \gamma} a(r_i) + \frac{\gamma}{N + \gamma} P_T \tag{Equation (4)}$$

where P_T is the total transmit power and:

$$a(r_i) = \frac{\gamma N_0 W}{N \beta(r_i)} \tag{Equation (5)}$$

[0027] Since a reference channel 114 must be received adequately throughout the operating range 30 of the cell 11, the transmit power requirement P_G for a reference channel 114 becomes:

$$P_G = \frac{N}{N + \gamma} a(R) + \frac{\gamma}{N + \gamma} P_T \tag{Equation (6)}$$

where R is the operating range 30 of the cell 11. The value of a(R) can be calculated easily for any propagation model. Accordingly, P_G is a constant plus a fraction of the total transmit power P_T . Since the total transmit power P_T is continuously monitored at the base station 100, the reference channel transmit power P_G is updated dynamically instead of transmitting it for the worst case, which corresponds to the maximum transmit power P_T that the base station 100 can transmit.

[0028] For example, for the aforementioned free space propagation model, the propagation loss is:

$$\beta(r) = \frac{\alpha}{r^2} \tag{from Equation 2}$$

where

$$\alpha = \frac{\lambda^2}{(4\pi)^2} \tag{from Equation 3}$$

and λ is the carrier frequency of the signal. In this model, at distance r_i :

$$\beta(r_i) = \frac{\alpha}{r_i^2} \tag{Equation 2}$$

and

$$a(r_i) = \frac{\gamma N_0 W}{\alpha N} R_i^2. \tag{from Equations 2 and 5}$$

[0029] Substituting R for the operating range 30 of the cell 11:

$$a(R) = \frac{\gamma N_0 W}{\alpha N} R^2, \tag{from Equations 2 and 5}$$

we have

$$P_G = \frac{\gamma}{\gamma + N} \frac{N_0 W}{\alpha} R^2 + \frac{\gamma}{\gamma + N} P_T \tag{from Equation 6}$$

Therefore, using the free space propagation model, the optimum reference channel transmit power is given by a constant term, which is proportional to the square of the cell radius, plus a variable term which is a function of the total transmit power P_T .

[0030] The significance of the present invention can be further illustrated by the following numerical example. Suppose system parameters are given as:

[0031] $\gamma=4$ (desired signal to noise ratio)

[0032] $N=130$ (processing gain)

[0033] $W=10 \times 10_6$ (transmit bandwidth)

[0034] $N_0=4 \times 10^{-21}$ (white noise density)

[0035] $R=30 \times 10^3$ m (30 km cell radius)

[0036] $\lambda=0.1667$ m (corresponding to 1.9 GHz carrier frequency).

[0037] Using the free space propagation model:

$$\alpha = \frac{(0.1667)^2}{(4\pi)^2} = 1.76 \times 10^{-4} \tag{from Equation 3}$$

[0038] Therefore, when the total power P_T transmitted from the base station is 100 watts, the reference channel transmit power P_G should be:

$$P_G = \left[\frac{4}{130 + 4} \right] \times \left[\frac{4 \times 10^{-21} \times 10 \times 10^6}{1.76 \times 10^{-4}} \right] \times (3 \times 10^4)^2 + \left[\frac{4}{130 + 4} \right] \times 100 = 3 \text{ Watts}$$

(from Equation 6)

[0039] Referring to FIG. 4, the method 200 for dynamically controlling the reference channel transmit power P_G is shown. Once all of the system parameters have been defined (step 202) and several constants are calculated ($\beta(R)$, $a(R)$) (step 204), the processor 108 then calculates A and B, which are used to determine the reference channel power level P_G (step 206). The total transmit power is measured at the base station 100 (step 208) and the desired reference channel power level P_G is calculated (step 210) using the formula:

$$P_G = A + B * P_T$$

Equation (7)

[0040] Once the desired reference channel power level P_G is calculated (step 210), all of the reference channels 114 are set to the calculated power level (step 212). This process is then repeated (step 214) to continually monitor the total transmit power at the base station 100 to dynamically control the power level of the reference channels 114.

[0041] The required transmit power for a reference channel 114 can change by as much as 12 dB depending on the traffic load of the cell 11. As a result, in an application where the reference channel power level P_G is set such that it is sufficient under the highest traffic load expected (i.e., worst case), the reference channel transmit power level P_G will exceed the required power level necessary most of the time. The method of the present invention controls the reference channel transmit power level P_G optimally by reducing it when the traffic load is light and increasing it when the traffic load is high such that reliable communications are maintained at all times. In this manner, the spillover to neighboring cells is kept at minimum possible levels and overall system capacity is increased.

[0042] Although the invention has been described in part by making detailed reference to certain specific embodiments, such details is intended to be instructive rather than restrictive. It will be appreciated by those skilled in the art that many variations may be made in the structure and mode of operation without departing from the spirit and scope of the invention as disclosed in the teachings herein.

What is claimed is:

1. In a cellular wireless communication system including a plurality of base stations and wireless transmit/receive units (WTRUs) wherein each base station transmits a reference signal over an entire range of a cell, a method for controlling transmit power of the reference signal, the method comprising:

a base station measuring a total transmit power level of combined signals on a channel specifically assigned to a WTRU and a reference signal; and

the base station adjusting a transmit power level of the reference signal based on the total transmit power level of the combined signals.

2. The method of claim 1, wherein the total transmit power level is measured after combining signals on a channel specifically assigned to a WTRU and the reference signal.

3. The method of claim 1, wherein individual transmit power levels are measured at each assigned channel and a reference channel, and the total transmit power level is measured by summing the individual transmit power levels.

4. The method of claim 1, wherein the total transmit power level is measured after transmission of combined signals on a channel specifically assigned to a WTRU and the reference signal.

5. The method of claim 1, wherein the transmit power level of the reference signal is determined based on at least one of: a desired signal-to-noise ratio (SNR), a processing gain, a transmit bandwidth, a noise density, a cell radius, and a carrier frequency.

6. The method of claim 1, wherein the transmit power level of the reference signal is determined using at least one of: a free space propagation model, a Hata model, and a break-point model.

7. The method of claim 1, wherein the transmit power level of the reference signal is adjusted continuously.

8. The method of claim 1, wherein the transmit power level of the reference signal is adjusted on a periodic basis.

9. In a cellular wireless communication system including a plurality of base stations and wireless transmit/receive units (WTRUs) wherein each base station transmits a reference signal over an entire range of a cell, an apparatus for controlling transmit power of the reference signal, the apparatus comprising:

a transmit power measurement unit configured to measure a total transmit power level of combined signals on a channel specifically assigned to a WTRU and a reference signal; and

a reference channel power control processor configured to adjust a transmit power level of the reference signal based on the total transmit power level of the combined signals.

10. The apparatus of claim 9, wherein the transmit power measurement unit is configured to measure the total transmit power level after combining signals.

11. The apparatus of claim 9, wherein the transmit power measurement unit is configured to:

measure individual transmit power levels at each assigned channel and a reference channel; and

sum the individual transmit power levels to calculate the total transmit power level.

12. The apparatus of claim 9, wherein the transmit power measurement unit is configured to measure the total transmit power level after transmission of the combined signals.

13. The apparatus of claim 9, wherein the reference channel power control processor is configured to determine the transmit power level of the reference signal based on at least one of: a desired signal-to-noise ratio (SNR), a processing gain, a transmit bandwidth, a noise density, a cell radius, and a carrier frequency.

14. The apparatus of claim 9, wherein the reference channel power control processor is configured to determine

the transmit power level of the reference signal using at least one of: a free space propagation model, a Hata model, and a break-point model.

15. The apparatus of claim 9, wherein the reference channel power control processor is configured to adjust the transmit power level of the reference signal continuously.

16. The apparatus of claim 9, wherein the reference channel power control processor is configured to adjust the transmit power level of the reference signal on a periodic basis.

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