



(19) **United States**

(12) **Patent Application Publication**

Bongfeldt

(10) **Pub. No.: US 2002/0045461 A1**

(43) **Pub. Date: Apr. 18, 2002**

(54) **ADAPTIVE COVERAGE AREA CONTROL IN AN ON-FREQUENCY REPEATER**

Publication Classification

(51) **Int. Cl.⁷** **H04B 7/00**
(52) **U.S. Cl.** **455/522; 455/69; 455/11.1**

(76) **Inventor: David Bongfeldt, Stittsville (CA)**

Correspondence Address:
Swabey Ogilvy Renault
Suite 1600
1981 McGill College Avenue
Montreal, QC H3A 2Y3 (CA)

(21) **Appl. No.: 09/919,959**

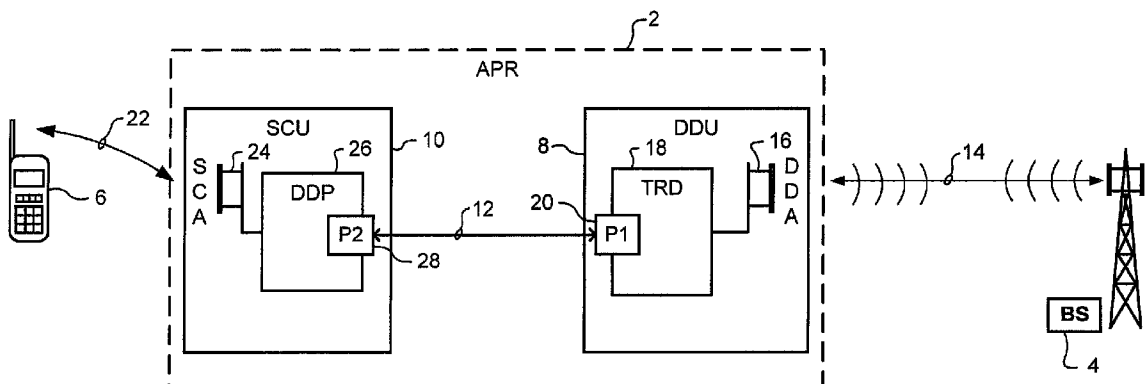
(22) **Filed: Aug. 2, 2001**

(30) **Foreign Application Priority Data**

Oct. 18, 2000 (CA) 2,323,881

(57) **ABSTRACT**

A system operates to adaptively control the coverage area of an on-frequency repeater. First RF signals received from a transceiver (such as a base station, or a subscriber's wireless communications device) are detected using a broadband detector, narrowband down converter and detector, and these detected signals are monitored by a micro controller. The micro controller operates, under control of suitable software implementing an Adaptive Control Algorithm, to adjust the ERP of second RF signals transmitted to the transceiver to thereby control the coverage area of the repeater, and maintain a substantially constant power level of the second RF signals received by the transceiver.



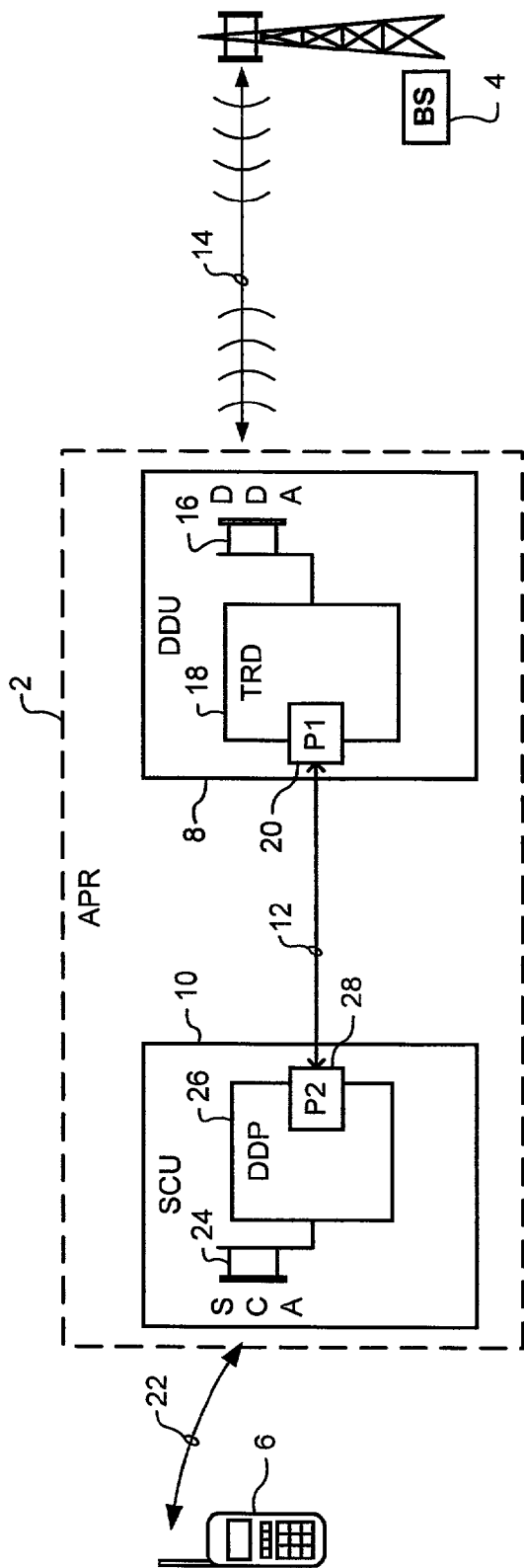


Figure 1

Figure 2

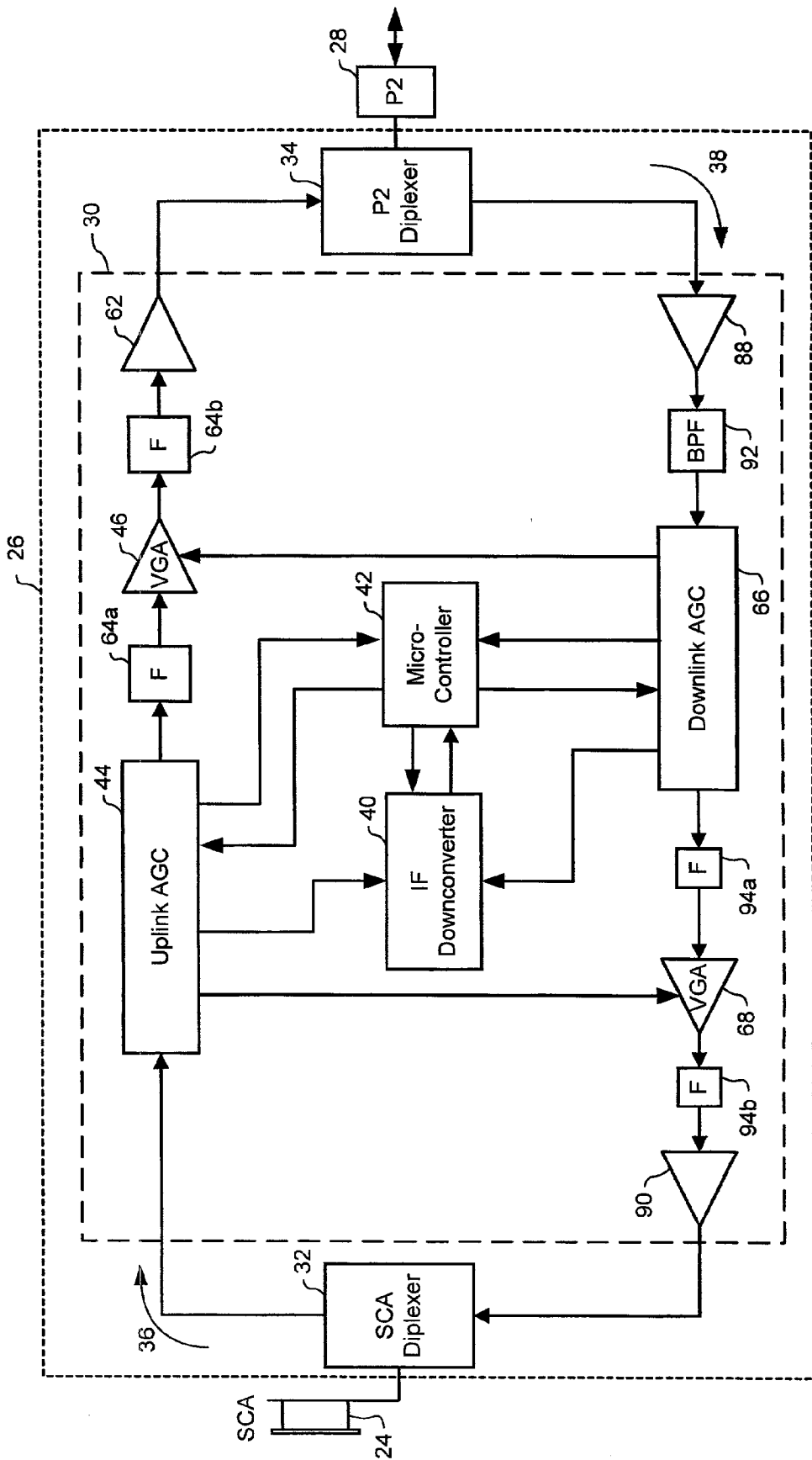


Figure 3

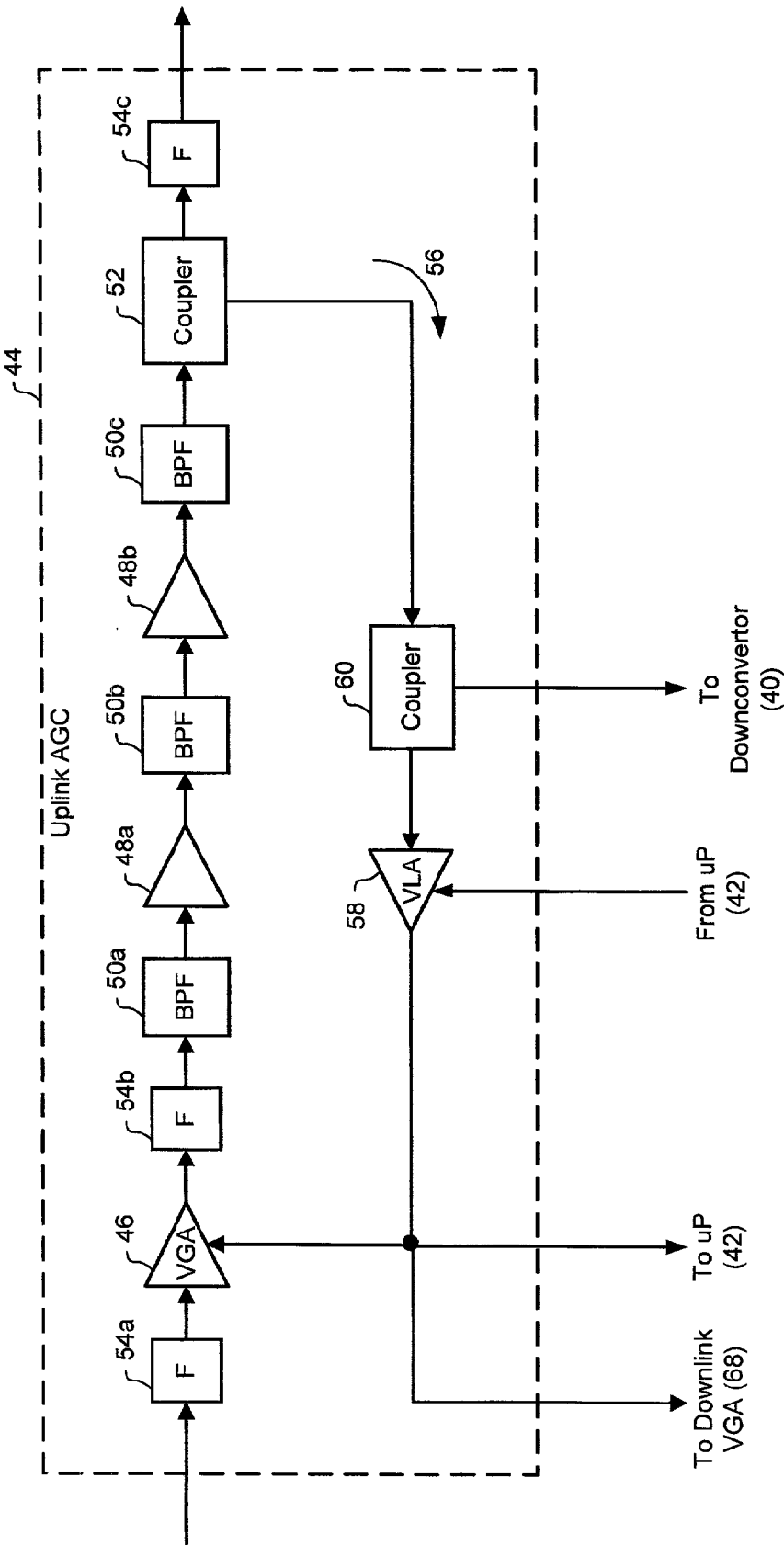


Figure 4

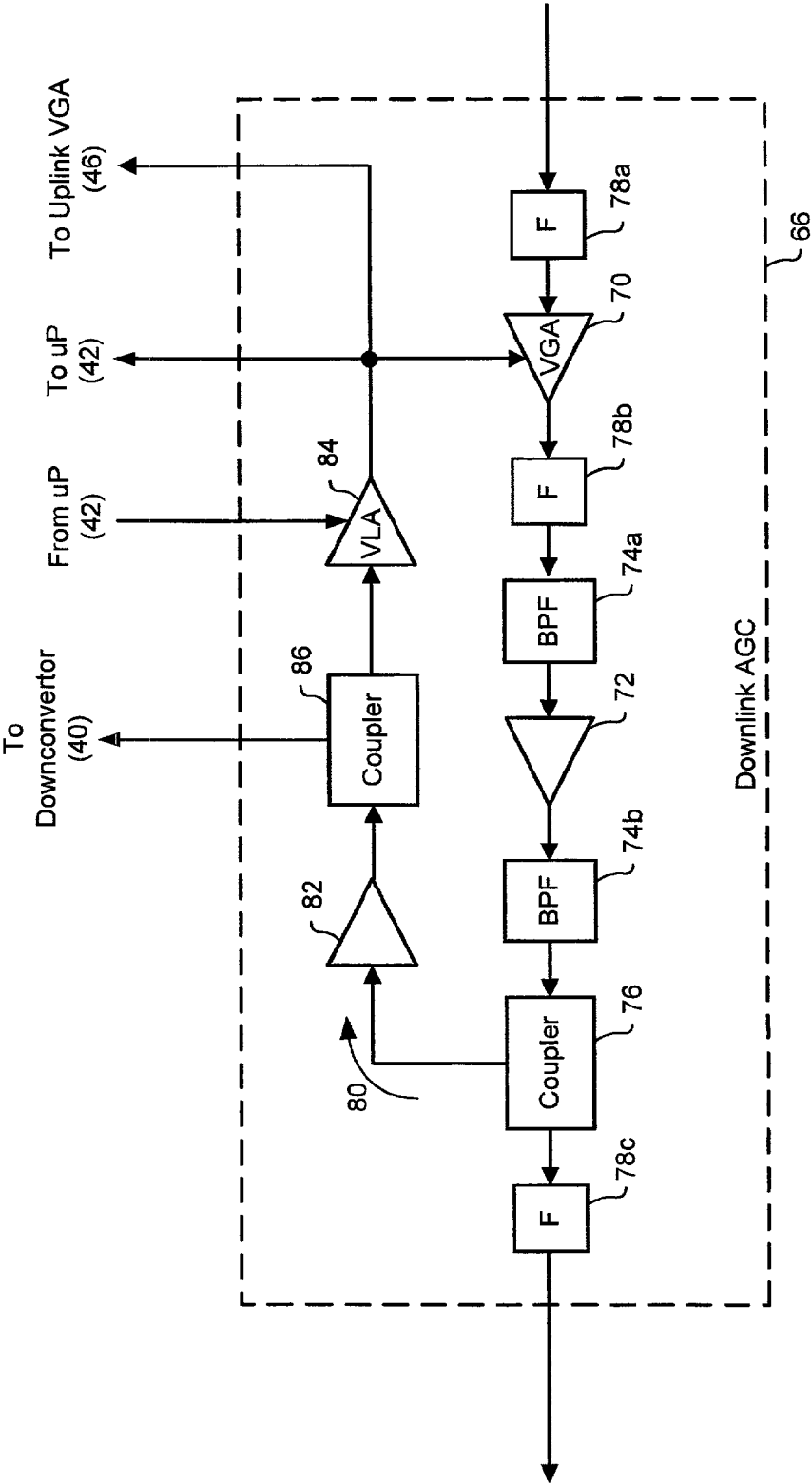
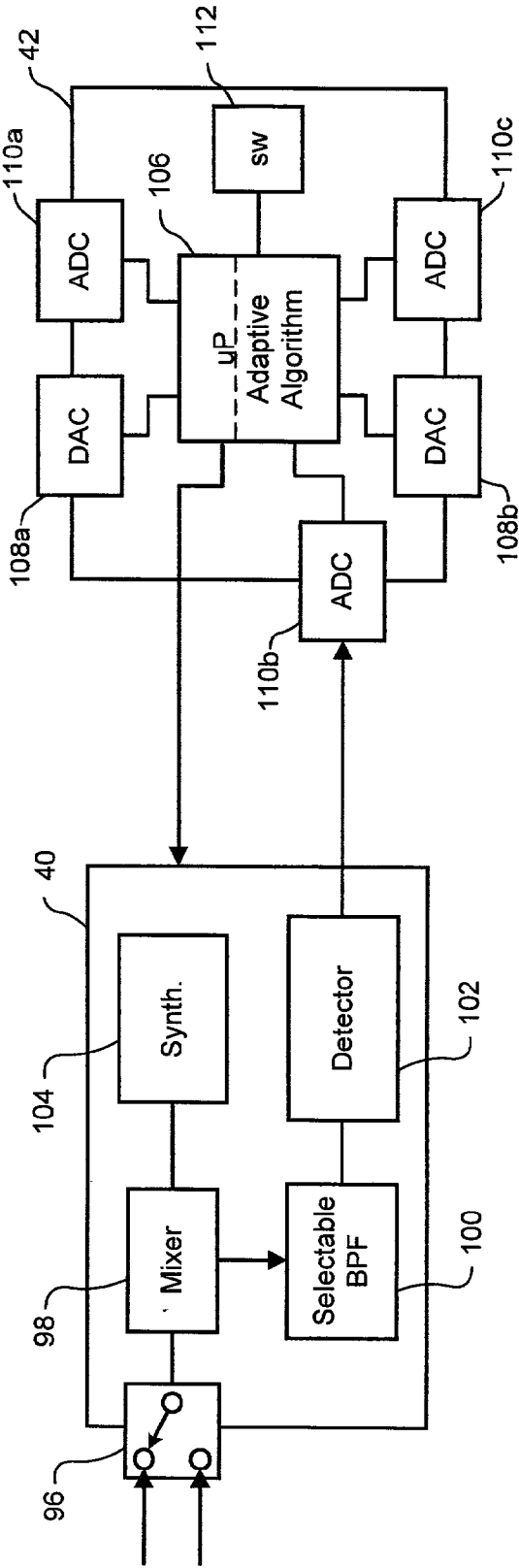


Figure 5



ADAPTIVE COVERAGE AREA CONTROL IN AN ON-FREQUENCY REPEATER

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application is based on, and claims priority of, U.S. patent application Ser. No. 09/809,218, filed on Mar. 16, 2001.

MICROFICHE APPENDIX

[0002] Not Applicable.

TECHNICAL FIELD

[0003] The present application relates to wireless access networks and, in particular, to a method and system for enabling Adaptive-Coverage Area Control in an on-frequency repeater.

BACKGROUND OF THE INVENTION

[0004] In the modern communications space, wireless access networks are increasingly popular, as they enable subscribers to access communications services without being tied to a fixed, wireline communications device. Conventional wireless access network infrastructure (e.g., base stations) is typically "built out", by a network service provider, using a network-centric approach. Thus the build-out normally begins with major Metropolitan Service Areas (MSAs) using base stations located at the center of overlapping coverage areas or "cells". The build-out, and corresponding wireless communications services, subsequently migrates outward from the MSAs to areas of lower population/service densities (e.g., urban to suburban to rural, etc.). At some point, usually dictated by economics, the build-out slows and/or becomes spotty leaving many individual wireless subscribers with unreliable or non-existent service.

[0005] On-frequency repeaters are known in the art for improving wireless services within defined regions of a wireless network (e.g., within a building or a built-up area). Such on-frequency repeaters are typically provided by the wireless network provider in order to improve signal quality in high noise or attenuation environments, where signal levels would otherwise be too low for satisfactory quality of service. In some cases, a wireless network provider may install a repeater in order to improve service in an area lying at an edge of the coverage area serviced by a base station, thereby effectively extending the reach of the base-station.

[0006] Prior art repeaters are part of a network-centric view of the wireless network space, in that they are comparatively large systems provided by the network provider in order to improve wireless service to multiple subscribers within a defined area. As such, they form part of the network 'build-out plan' of the network provider. These systems suffer the disadvantage in that an individual subscriber cannot benefit from the improved services afforded by the repeater unless they happen to be located within the coverage area of the repeater. However, there are many instances in which wireless subscribers may reside or work in areas where the coverage area of the wireless network is unreliable. Typical examples include mobile subscribers, and subscribers located in suburban and rural areas. Also, in-building coverage can be unreliable even within MSAs,

depending on the size, location and construction of buildings and/or other obstacles. In such cases, it may be uneconomical for a network provider to build-out the network to provide adequate coverage area, thereby leaving those subscribers with inadequate wireless services.

[0007] Accordingly, Applicant's co-pending United States Patent Application No. 09/809,218, filed on Mar. 16, 2001 and entitled Adaptive Personal Repeater, the contents of which are incorporated herein by reference, provides a method and apparatus that enables an individual subscriber to cost-effectively access high quality wireless communications services, independently of the location of the subscriber. The Adaptive Personal Repeater (APR) transparently mediates signaling between a subscriber's wireless communications device (WCD) and a transceiver (base station) of a wireless communications network. The APR includes a Directional Donor Unit (DDU) and a Subscriber Coverage Unit (SCU). The DDU maintains a network link with the base station of the wireless communications network. The SCU maintains a local link with the WCD within a personal wireless space of the APR. Total system gain is divided between, and integrated with, the DDU and the SCU, so that a separate gain and system control unit is not required. This division of system gain also enables high-performance on-frequency repeater functionality to be obtained without the use of high-cost components and building blocks.

[0008] As described in U.S. patent application Ser. No. 09/809,218, the APR represents a subscriber-centric solution for improving wireless services as required by one or more subscribers, and in a manner that is transparent to the network. However, in order to provide this functionality, it is necessary for the repeater to provide sufficient system gain in each of the uplink and downlink paths to compensate for propagation losses in these paths. On the other hand, if the gain (in either the uplink or downlink paths) is too high, the repeater will radiate unnecessarily high signal powers to the subscriber's WCD and/or the base station. In an environment in which there is more than one APR in use, radiation of excessive signal power in the downlink path can cause interference (in the form of multiple overlapping coverage areas) with other subscribers.

[0009] Additionally, where coverage areas overlap, i.e., the base station coverage area and the APR coverage area(s) downlink RF signals destined for a subscriber's WCD are transmitted through a single or all involved APRs. The resulting multiple propagation paths of the downlink RF signals produce severe multi-path interference, including null-zones where the downlink RF signals propagating in each path are equal in amplitude and phase offset by approximately 180° (and thus cancel each other).

[0010] A single APR radiating excessive power in the downlink path may cause interference to other subscribers outside the personal wireless space. Similarly, radiation of excessive signal power to the base-station may cause interference with other base-stations and/or other users of the wireless communications network.

[0011] Accordingly, a method and apparatus capable of adaptively controlling a coverage area of an on-frequency repeater, in order to minimize the ERP of signals transmitted by the repeater while compensating for the distance from the base station and movement of a transceiver relative to the repeater, at a moderate cost, remains highly desirable.

SUMMARY OF THE INVENTION

[0012] An object of the present invention is to provide an apparatus for adaptively controlling a coverage area of an on-frequency repeater of a wireless communications network.

[0013] Accordingly, an aspect of the present invention provides a method of adaptively controlling a coverage area of a transceiver of a wireless communications network. A power level of a first RF signal received from a second transceiver of the wireless communications network is detected and compared to a predetermined threshold. Based on the comparison result, an effective radiated power (ERP) of a second RF signal transmitted to the second transceiver is controlled, such that the coverage area is adaptively controlled to expand and contract, during a communications session, to maintain a reliable wireless link with the second transceiver.

[0014] Another aspect of the present invention provides a system for adaptively controlling a coverage area of a transceiver of a wireless communications network. A detector is adapted to detect a power level of a first RF signal received from a second transceiver of the wireless communications network. A controller operates to control an effective radiated power (ERP) of a second RF signal transmitted to the second transceiver, using the detected power level, so as to maintain a substantially constant power level of the second RF signal received by the second transceiver.

[0015] In embodiments of the invention, the second transceiver may be any one of a base station, a repeater and a subscriber's wireless communications device. The detector and controller may be provided as any suitable combination of hardware and/or software.

[0016] In preferred embodiments, the detector includes at least a narrow-band detector adapted to detect the first RF signal within a respective first wideband signal path of the transceiver.

[0017] The controller preferably includes a processor and a variable gain amplifier (VGA). The VGA is responsive to a control signal from the processor to control the ERP of the second RF signal, by adjusting a gain of a respective second wideband signal path conveying the second RF signal through the transceiver.

[0018] The processor may be adapted to compare the detected power level to a predetermined threshold. This predetermined threshold may be an initial power level of the first RF signal. Alternatively, the predetermined threshold may be based on a format of the first RF signal. In such cases, the processor may be further adapted to: analyze the first RF signal to determine the format of the first RF signal; and select the threshold from among a set of predetermined threshold values, based the determined format.

[0019] In some embodiments, the processor is further adapted to: estimate a variation in propagation loss between the transceivers based on the comparison result; estimate a variation in the ERP of the second RF signal required to compensate the estimated propagation loss variation; and generate the control signal to control the variable gain amplifier in accordance with the estimated ERP variation.

[0020] As described above, the first and second RF signals are preferably conveyed within respective first and second

wideband signal paths. Each of these wideband signal paths has a bandwidth corresponding to a respective one of an uplink channel bandwidth and a downlink channel bandwidth of the wireless communications network. This bandwidth may, for example, be about 25 MHz.

[0021] Each wideband signal path may include first and second gain control blocks, which are preferably connected in series. The first gain control block may be adapted to selectively control a first gain of the respective wideband signal path based on a power level of RF signals in the wideband signal path. The second gain control block may be adapted to selectively control a second gain of the respective wideband signal path based on a power level of RF signals in the other wideband signal path.

[0022] Preferably, the first gain of the respective wideband signal path is inversely proportional to the received power level of RF signals (i.e., at an input of the first gain control block). Thus changes in the first gain reflect corresponding changes in the received level of the first RF signals between the transceiver and the repeater, which when averaged are primarily a function of changing distance between the two devices (at least for the duration of a communications session). This information can then be used to control the ERP of the second RF signals transmitted to the transceiver, to thereby expand or contract the coverage area of the repeater as the transceiver moves relative to the repeater.

[0023] Multi-path signal cancellation can occur between the repeater and the transceiver. The first gain control block is allowed to react to instantaneous changes in the received signal level of the first RF signals due to multi-path and therefore negating this effect in the controlled coverage area.

[0024] In some embodiments, the first gain control block comprises an Automatic Gain Control (AGC) block including a Variable Gain Amplifier (VGA); an AGC feed-back loop; and a feed-back gain controller. The Variable Gain Amplifier (VGA) operates to control the first gain of the respective wideband signal path in response to a gain control signal, which is supplied by the AGC feed-back loop. The feed-back gain controller operates to control a power level of the gain control signal supplied to the VGA, in response to an AGC control signal from the micro controller.

[0025] The feed-back gain controller may be a variable amplifier (such as, for example, a variable logarithmic amplifier) disposed in the AGC feed-back loop and operatively coupled to receive the AGC control signal from the micro controller.

[0026] The AGC feed-back loop may further include a coupler adapted to supply a sample of RF signals in the respective wideband signal path to the narrowband detector.

[0027] In some embodiments, the second gain control block comprises a slaved variable gain amplifier disposed in one of the wideband signal paths, and adapted to selectively control the respective second gain of one wideband signal path (and thus the ERP of RF signals transmitted from that path) in accordance with the gain control signal supplied to the AGC VGA of the other wideband signal path. Alternatively, the second gain control block may be controlled directly by a control signal supplied by the micro controller.

[0028] In some embodiments, the narrowband detector comprises: a synthesizer adapted to generate a synthesizer

signal having a selected frequency; an input adapted to receive an RF sample signal from one of the first and a second wideband signal paths; a mixer adapted to generate an intermediate frequency based on the synthesizer signal and the RF sample signal; a signal isolator adapted to isolate, from the RF sample signal, RF signals lying within a narrow pass-band centered on the intermediate frequency; and a detector unit adapted to detect at least a power level of the isolated RF signals.

[0029] The synthesizer may be adapted to select a frequency of the synthesizer signal using a synthesizer control signal from the micro controller.

[0030] The input may comprise a switching input adapted to selectively supply RF signals from one of the first and a second wideband signal paths to the mixer.

[0031] The signal isolator may comprise a selectable filter adapted to selectively attenuate a portion of the RF sample signal lying outside the narrow pass-band, which may, for example, have a bandwidth of approximately 30 KHz, 200 KHz or 1.25 MHz. The selectable filter may also be adapted to adjust the bandwidth of the narrow pass-band in response to a control signal from the micro controller.

BRIEF DESCRIPTION OF THE DRAWINGS

[0032] Further features and advantages of the present invention will become apparent from the following detailed description, taken in combination with the appended drawings, in which:

[0033] FIG. 1 is a block diagram schematically illustrating principle elements of an exemplary Adaptive Personal Repeater in which the present invention may be deployed;

[0034] FIG. 2 is a block diagram schematically illustrating principle elements of an exemplary Intelligent Gain Controller (IGC) in accordance with an embodiment of the present invention;

[0035] FIG. 3 is a block diagram schematically illustrating principle elements of an exemplary uplink AGC usable in the IGC of FIG. 2;

[0036] FIG. 4 is a block diagram schematically illustrating principle elements of an exemplary downlink AGC usable in the IGC of FIG. 2; and

[0037] FIG. 5 is a block diagram schematically illustrating principal elements of exemplary down converter and micro controller modules usable in the IGC of FIG. 2.

[0038] It will be noted that throughout the appended drawings, like features are identified by like reference numerals.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

[0039] The following description utilizes exemplary power levels, power ranges, channel frequencies and band-widths in order to illustrate various features of the present invention. Those skilled in the art will appreciate, however, that the present invention is by no means limited to such values. On the contrary, those skilled in the art will readily understand that the present invention can be deployed for use in conjunction with any wireless communications network, and it is to be expected that the power levels, power

ranges, channel frequencies, and band-widths stated herein will be modified to conform to the requirements of the communications network in question. Such modifications are considered to be well within the purview of those of ordinary skill in the art, and lie within the intended scope of the appended claims.

[0040] The present invention provides a system for adaptively controlling a coverage area of an on-frequency repeater, such as, for example, an Adaptive Personal Repeater (APR) described in applicant's co-pending U.S. patent application Ser. No. 09/809,218. In general, an on-frequency repeater operates to mediate RF signal traffic between transceivers of the wireless communications network. Thus the APR creates a local wireless space encompassing one or more mobile transceivers (e.g., subscribers' wireless communications device(s)), and maintains a reliable fixed wireless link to a fixed transceiver (e.g., a base station) in order to "reach back" into the reliable coverage area of the wireless communications network to provide high quality wireless services in an otherwise poorly serviced area of the network. The system of the invention operates to control the coverage area of the repeater to facilitate reliable communications between the subscriber's wireless communications device(s) and the network, while mitigating potential interference. FIG. 1 is a block diagram schematically illustrating principle elements of an exemplary repeater in which the system of the present invention may be deployed.

[0041] As shown in FIG. 1, the repeater 2 is functionally positioned between a base station 4 of the wireless communications network (not shown) and the subscriber's Wireless Communications Device (WCD) 6. The repeater 2 is an "on-frequency" repeater, in that uplink and downlink RF signals are conveyed through the repeater 2 without altering the respective channel frequencies. The repeater 2 selectively receives and controls (i.e., amplifies or attenuates) RF signals, without performing any signal formatting or protocol conversion, thereby rendering the repeater 2 transparent to both the base station 4 and the WCD 6. The subscriber's WCD 6 may take the form of any conventional wireless communications device, such as, for example, Personal Digital Assistants (PDA's), wireless telephone handsets, pagers, and one and two-way wireless messaging devices.

[0042] It will be appreciated that the subscriber may possess multiple WCDs 6, and may use any one or more WCDs 6 simultaneously. Similarly, multiple subscribers may be located within the wireless space of a single repeater 2. However, for ease of description of the invention, the illustrated embodiment includes a single WCD 6 within the wireless space defined by the repeater 2.

[0043] In the embodiment of FIG. 1, the repeater 2 comprises a Directional Donor Unit (DDU) 8 and a Subscriber Coverage Unit (SCU) 10. The DDU 8 and SCU 10 may be suitably coupled to each other, for example via a coaxial cable 12, as shown in FIG. 1. In other embodiments, the DDU 8 may be connected to a number of SCUs via respective coaxial cables 12 to provide multiple coverage areas.

[0044] The Directional Donor Unit (DDU) 8 operates to establish and maintain a network link 14 between the repeater 2 and the base station 4. Preferably the DDU 8 is designed to receive downlink signals from the base station

4 at power levels as low as -120 dBm, and transmit uplink signals to the base station 4 at an ERP of up to $+37$ dBm. This transmit and receive performance of the DDU 8 enables maintenance of the network link 14 with the base station 4, even when the DDU 8 is located well beyond the conventional cell and/or network coverage area boundary. In the illustrated embodiment, the DDU 8 is provided as a single port active antenna comprising a Directional Donor Antenna (DDA) 16 integrated with a Transceiver Diplexer (TRD) 18. A bi-directional port 20 couples the DDU 8 to the SCU 10 via the coaxial cable 12.

[0045] The Subscriber Coverage Unit (SCU) 10 operates to maintain a local wireless link 22 between the repeater 2 and the subscriber's WCD 6, and define the coverage area of the repeater 2. It is anticipated that the coverage area will be very much smaller than a conventional cell of the wireless communications network. For example, in some embodiments, it is expected that the coverage area will extend 25 m (or less) from the SCU 10. Other embodiments may provide a larger or smaller coverage area, as desired.

[0046] In the illustrated embodiment, the Subscriber Coverage Unit (SCU) 10 is provided as a single port active antenna comprising a Subscriber Coverage Antenna (SCA) 24 integrated with a dual-directional processor (DDP) 26. A bi-directional port 28 couples the SCU 10 to the DDU 8 via the coaxial cable 12.

[0047] In accordance with the present invention, the DDP 26 comprises an Intelligent Gain Controller (IGC) 30 connected between an SCA diplexer 32 and a port diplexer 34. As shown in FIG. 2, the SCA diplexer 32 is coupled to the SCA 24, and the port diplexer 34 is coupled to the bi-directional port 28. These diplexers 32 and 34 operate to separate uplink and downlink signal paths 36 and 38 at the SCA 24 and port 28, respectively. The diplexers 32 and 34 also define and limit the frequency band(s) over which the IGC 30 must operate and maintain stability.

[0048] As shown in FIG. 2, the IGC 30 is provided as a hybrid RF, analog and digital processing module capable of detecting and selectively controlling (i.e., amplifying and/or attenuating) RF signal traffic between the base station 4 and the WCD 6. The use of a hybrid processing module in this manner enables the IGC 30 to utilize mathematical (i.e., analog) signal conditioning and gain control techniques, in combination with knowledge-based (i.e., software) control of signal detection and system behaviour.

[0049] As shown in FIG. 2, the IGC 30 includes a wide-band uplink signal path 36 and a wide-band downlink signal path 38 coupled between the diplexers 32 and 34, and an IF down-converter and narrow-band detector 40, all of which are controlled by a micro controller 42 in accordance with an Adaptive Control Algorithm (ACA). Each of the uplink and downlink paths 36 and 38 are designed to control, condition and process RF signals within their respective wide-band uplink and downlink channels.

[0050] In general, the band-width of the wide-band signal paths 36, 38 will be determined by the communications network, typically in accordance with published standards. For example, in North America, publicly accessible cellular communications networks utilize a 25 MHz uplink and downlink channel bandwidth centered on 836.5 MHz and 881.5 MHz, respectively. Accordingly, for North American

installations, the uplink and downlink signal paths 36 and 38 can be suitably designed to process RF signals over the entire corresponding 25 MHz band-widths or sub-bands at the 25 MHz bandwidth designated by carrier A or B. However, it will be appreciated that different band-widths, and different center frequencies, can be utilized, as desired.

[0051] In general, RF signal traffic received by the sCU 10 is detected by the uplink AGC 44 and downlink AGC 66 broadband detectors and the narrowband down-converter and detector 40, and used by the micro controller 42 to adaptively control the coverage area of the repeater 2 by controlling the ERP of RF signal traffic transmitted to the WCD 6 through the SCA 24.

[0052] More particularly, the IGC 30 of the present invention operates to control (amplify and/or attenuate) uplink channel RF signals received from the WCD 6 with a widely varying received power (e.g., between 0 and -60 dBm) for transmission to the base station 4 with a substantially constant repeater uplink Effective Radiation Power (ERP). In this respect, the repeater uplink ERP can also be adjusted (by operation of the IGC 30) to a minimum value consistent with satisfactory link performance and prevention of system oscillation. However, following set-up of the network wireless link 14, it is anticipated that little, if any, adjustment in the repeater uplink ERP will be required, at least within the duration of a communications session. It is expected that a repeater uplink ERP of between about -23 dBm and about $+37$ dBm (depending principally on the distance between the repeater 2 and the base station 4) will yield satisfactory performance for most installations.

[0053] In the downlink path, the IGC 30 controls the downlink channel RF signals received from the base station 4 with a substantially constant received power for transmission to the WCD 6 with a varying repeater downlink ERP. The power of downlink RF signals received from the base station 4, will normally be determined during set-up of the network wireless link 14, and thereafter will only change significantly, at least within the duration of a communications session, if multi-path changes occur or if the network changes. It is anticipated that downlink RF signals received from the base station 4 will normally have a power of between about -120 and -60 dBm, depending largely on the ERP of the base station 4 and the distance between the base station 4 and the repeater 2. The repeater downlink ERP will be continuously adjusted (by the IGC 30) to a minimum value consistent with satisfactory performance of the local link 22, and so adaptively control the coverage area, as will be described in greater detail below. It is anticipated that a repeater downlink ERP of up to about -10 dBm will yield satisfactory performance for most installations.

[0054] Referring to FIG. 2, the uplink path 36 comprises a wide-band uplink Automatic Gain Controller (AGC) 44 and a slaved variable gain amplifier (VGA) 46. The uplink AGC 44 interfaces with the down-converter 40 and the micro controller 42, as will be described in greater detail below. In preferred embodiments, the uplink path 36 is designed to receive, process and transmit RF signals across the entire uplink channel RF operating band. This processing bandwidth is only limited by the network system bandwidth. For example, North American 800 MHz cellular networks utilize an uplink frequency bandwidth of 25 MHz centered at 836.5 MHz and is divided into carrier A and B sub-bands.

[0055] The uplink path 36 preferably provides substantially constant output leveling over a wide input range. Thus the ERP of uplink RF signals transmitted to the base station 4 will be substantially independent of variations in the signal power of uplink RF signals received from the WCD 6. In the embodiment of FIG. 3, the uplink AGC 44 is provided as an extremely fast, wide dynamic range, highly linear block including a single VGA stage 46, fixed gain amplifiers 48a and 48b cascaded with band-pass filters 50, and a directional coupler 52. Inter-stage attenuators 54a-54c may also be included to optimize performance. The gain of the uplink AGC 44 has an inverse relationship to the received power of uplink RF signals. Accordingly, the uplink AGC 44 gain is automatically increased as the received uplink RF signal power decreases and the total uplink gain can be controlled by the micro-controller 42.

[0056] The VGA 46 preferably has approximately 60 dB of gain variation, and is cascaded with the fixed gain amplifiers 48 to enhance system linearity. The BPFs 50 following the VGA 46 limit the VGA noise to the uplink band, thereby preventing out-of-band signals from capturing the uplink AGC 44 and saturating the uplink output amplifier 62.

[0057] The directional coupler 52, which may be a 17 dB directional coupler, samples the uplink RF signal downstream of the VGA 46. The sample signal is supplied to a feedback path 56 comprising an RF Variable Log Amplifier (VLA) 58 and a feedback directional coupler 60 which samples the RF signal within the feedback path 56 and supplies the sample signal to the down-converter 40. The RF VLA 58 is a variable detection amplifier controlled by the micro controller 42. The output of the RF VLA 58 supplies a gain control signal to the uplink AGC VGA 46 and the downlink slaved VGA 68 (thereby controlling downlink path ERP), and may also be supplied to the micro controller 42 for decision making in accordance with the Adaptive Control Algorithm (ACA).

[0058] The feedback path 56 provides a 25 MHz bandwidth path which operates to ensure system stability by providing substantially instantaneous RF AGC feedback. The feedback path 56 closes the uplink AGC loop, which in turn limits system oscillation by automatically adjusting gain of the VGA 46 in the event of inadequate isolation between the DDA 16 and the SCA 24. The feedback path 56 also provides a means by which the gain of the uplink AGC 44 and the downlink slaved VGA 68 can be forced to a low level by the micro controller 42 to maintain stability during system setup, thereby ensuring the detection of weak desired signals in the downlink path 38 without the need for initial system isolation maximization, and/or to disable the system if a major fault is detected.

[0059] The uplink slaved VGA 46 preferably has approximately 60 dB of gain variation, and accepts a gain control input from the downlink AGC 66 to provide the hardware means to adaptively minimize the uplink channel output power, and thereby mitigate potential interference to other base stations 4. It can be appreciated that in other embodiments of the preferred invention the slaved VGA 46 may be controlled directly by the micro controller 40 to accomplish the same task. As well, this processing scheme allows send changes in losses of coaxial cable 12 that may occur during installation to be compensated for automatically and therefore ensuring correct uplink output power.

[0060] As shown in FIG. 2, the uplink path 36 may also include an output amplifier stage 62, along with one or more inter-stage filters 64a, 64b. The uplink output amplifier 62 provides a fixed gain to compensate for losses in the coaxial cable 12, while the inter-stage filters 64a, 64b limit cascaded noise.

[0061] The downlink path 38 comprises a wide-band downlink automatic gain controller (AGC) 66, and a slaved variable gain amplifier (VGA) 68. The downlink AGC 66 interfaces with the down-converter 40 and the micro controller 42, as will be described in greater detail below. In preferred embodiments, the downlink path 38 is designed to receive, process and transmit the entire downlink RF channel operating band, for example, North American 800 MHz cellular network has a downlink frequency bandwidth of 25 MHz centered at 881.5 MHz and is divided into carrier A and B sub-bands.

[0062] The downlink AGC 66 preferably provides substantially constant output leveling over a wide input range. As shown in FIG. 4, the downlink AGC 66 is preferably provided as an extremely fast, wide dynamic range, highly linear block comprising a single VGA stage 70, a fixed gain amplifier 72 cascaded with a pair of band-pass filters 74a and 74b, and a directional coupler 76. Inter-stage attenuators 78a-78c may also be included to optimize performance.

[0063] The downlink AGC VGA 70 preferably has approximately 60 dB of gain variation, and is cascaded with the fixed gain amplifier 72 to enhance system linearity while minimizing the cascaded noise figure. The BPFs 74a and 74b operate to limit VGA noise to the 25 MHz downlink bandwidth, thereby preventing out-of-band signals from capturing the downlink AGC 66 and saturating the downlink path output amplifier 90.

[0064] The directional coupler 76, which may be a 17 dB directional coupler, samples the downlink RF signal downstream of the VGA 70. The sample signal is supplied to a feedback path 80 which includes a cascaded RF amplifier 82 and RF Variable Log Amplifier (VLA) 84, and a feedback directional coupler 86 which samples the RF signal within the feedback path 80 and supplies the sample signal to the down-converter 40. The RF VLA 84 is preferably a variable detection log amplifier controlled by the micro controller 42. The output of the RF VLA 84 supplies a gain control signal to the downlink AGC VGA 70 and the uplink path slaved VGA 46, and may also be supplied to the micro controller 42 for decision making in accordance with the ACA. The feedback path 80 preferably provides a 25 MHz bandwidth path which operates to ensure system stability by providing substantially instantaneous RF AGC feedback. The feedback path 80 closes the AGC loop, which in turn limits system oscillation by automatically adjusting gain of the VGA 70 in the event of inadequate isolation between the DDA 16 and SCA 24. The feedback path 80 also provides a means by which the gain of the downlink AGC 66 can be forced to a low level by the micro controller 42 to disable the system following detection of a major fault.

[0065] The downlink slaved VGA 68 preferably has about 60 dB of gain variation, and accepts a gain control input from the uplink path AGC 44 to provide a hardware means to adaptively minimize the downlink output power. Thus, for example, the downlink slaved VGA 68 operates to reduce gain in the downlink path 38, as the received power of uplink

RF signals increases, thereby reducing the coverage area of the subscriber's personal wireless space. It can be appreciated that in other embodiments of the preferred invention the slaved VGA 68 may be controlled directly by the micro controller 42 to accomplish the same task.

[0066] As shown in FIG. 2, the IGC downlink path 38 may also include a pre-amplifier 88, and an output amplifier stage 90. These elements can be cascaded with a band-pass filter (BPF) 92 and inter-stage attenuators 94a and 94b to reduce cascaded noise and optimize performance. The pre-amplifier 88 operates to preserve the S/N ratio established by the DDU 8, and buffers the port diplexer 34 from BPF 92. This BPF 92, together with the port diplexer 34, limits the downlink bandwidth to 25 MHz, rejecting both image and frequency crossover noise and any out-of-band signals, including RF signals in the uplink path 36. The output amplifier 90 provides a fixed gain to provide the necessary power output to the SCA 24.

[0067] As shown in FIG. 5, the down-converter 40 comprises a switching input 96, an active mixer 98, a selectable band pass filter 100, a log amp detector 102, and a synthesizer 104 which can be selectively tuned by the micro controller 42. The switching input 96 is controlled by the micro controller 42 to supply an RF sample signal from a selected one of the uplink and downlink AGCs 44 and 66 to the active mixer 98. Similarly, the synthesizer 104 is controlled by the micro controller 42 to supply an RF synthesizer signal to the mixer 98. The RF sample signal and the synthesizer signal are processed by the mixer 98, in a conventional manner, to generate an Intermediate frequency (IF) signal. This IF signal is used by the selectable BPF 100 to channel the RF sample signal by selectively attenuating portions of the RF sample signal lying outside a narrow pass-band centered on the IF. The output of the selectable BPF 100 is supplied to the detection log amplifier 102, which operates to detect the presence (and power level) of desired RF signals (in each of the uplink and downlink channels, depending on the state of the switching input 96). The output of the detection log amplifier 102 is supplied to the micro controller 42, and is used for decision making in accordance with the Adaptive Control Algorithm (ACA).

[0068] Thus, when the switching input 96 supplies an RF sample signal from the uplink AGC 44 to the mixer 98, the selectable BPF 100 and detection log amplifier 102 operate to detect the power level and number of desired RF signals within the uplink channel 36, and this information can be used by the micro controller 42 to determine the signal format, set the appropriate power (i.e., gain) in the uplink path 36 and, for each detected desired RF signal, tune the synthesizer 104 to the corresponding downlink channel frequency (e.g., 45 MHz above the frequency of the detected signal), if necessary.

[0069] Similarly, when the switching input 96 supplies an RF signal from the downlink AGC 66 to the mixer 98, the selectable BPF 100 and detection log amplifier 102 operate to detect weak desired signals within the downlink channel 38, and this information can be used by the micro controller 42 to determine the downlink signal format, set the appropriate power (i.e., gain) in the downlink path 38 and, for each detected desired RF signal, tune the synthesizer 104 to the corresponding uplink channel frequency (e.g., 45 MHz below the frequency of the detected RF signal), if necessary.

[0070] The design of the down-converter 40 enables the micro controller 42 to detect any number of weak desired uplink and downlink RF signals that are below either high-level wanted signals and/or adjacent carrier signals, or the system noise floor within a respective 25 MHz bandwidth. The micro controller 42 can provide a digital correction to each of the AGCs 44 and 66, thereby offsetting the respective leveled outputs to the weak desired signals. This arrangement enables the IGC 30 (and thus the repeater 2) to mediate signal traffic between the base station 4 and any number of WCDs 6 within the coverage area of the repeater 2.

[0071] The micro controller 42 comprises a micro-processor 106 operating under the control of suitable software that implements an Adaptive Control Algorithm (ACA), one or more Digital-to-Analog converters (DACs) 108 and Analog-to-Digital Converters (ADCs) 110 which operate, in a manner well known in the art, to provide translation between digital and analog signal formats, and thereby enable interaction between the micro controller 42 and other elements of the IGC 30. As will be described in greater detail below, the adaptive control algorithm provides the necessary processing control for IGC operation without intervention after installation. It may also control operation during system set-up, in order to simplify installation of the repeater 2.

[0072] As shown in FIG. 5, the micro controller 42 may also include a configuration switch 112 to enable the subscriber to control an operating configuration (or mode) of the micro controller 42. The configuration switch 112, which may be provided as a conventional DIP switch, may have one or more settings allowing the subscriber to select an operating configuration (or mode) of the micro controller 42. Exemplary settings of the configuration switch may include:

[0073] a "set-up" setting which may be used during installation of the repeater 2. For example, the micro controller 42 may reduce AGC gain (and thus transmission power levels) to enable the subscriber to adjust the placement and positioning of the DDU 8 and SCU 10;

[0074] a "run" setting which may be used during normal operation of the repeater 2;

[0075] a carrier A/B band select setting which may be used by the subscriber to select a desired carrier. Carrier A/B bands may be selected together or individually; and

[0076] one or more settings by which the subscriber can choose to define maximum and/or minimum coverage areas of the subscriber's personal wireless space, e.g., by causing the micro controller 42 to limit gain of the downlink AGC 66.

[0077] As mentioned previously, the micro-processor 106 operates under the control of suitable software that implements the Adaptive Control Algorithm (ACA). In general, the ACA provides knowledge-based control over the functionality of the IGC 30, thereby providing dramatically greater versatility than is possible with conventional (analog math-based) RF signal processing techniques. In accordance with the present invention, the ACA controls the IGC 30 to implement adaptive control of the coverage area of the repeater. This functionality is described in greater detail below.

[0078] In general, adaptive coverage area control according to the present invention comprises a technique of RF power management that enables the coverage area of the subscriber's personal wireless space to "breathe"; adaptively expanding and contracting to the position of the subscriber's WCD 6 relative to the SCA 24. This allows both the WCD 6 and the SCA 24 to radiate only the necessary powers needed to maintain reliable signaling over the local link 22. As the WCD 6 moves relative to the SCA 24, the coverage area of the personal wireless space changes continuously to adapt to the movement. As the WCD 6 moves towards the SCA 24, the IGC 30 causes the coverage area to contract, so that the coverage area of the repeater 2 is limited to just encompass the WCD 6. This can be accomplished by monitoring the signal power of uplink RF signals received from the WCD 6, and then adjusting the gain of the downlink VGA 68 to control the ERP of downlink RF signals accordingly. If two or more WCDs are being used simultaneously, then the IGC 30 can expand the coverage area to accommodate the WCD located furthest from the SCA 26 (or transmitting the weakest uplink RF signals). This can be achieved by measuring the power of uplink RF signals received from each of the wireless communications devices, and adjusting the downlink transmit power based on the measured signal power levels of the weakest signal.

[0079] As described above, the uplink and downlink paths 36 and 38 are wide bandwidth RF signal paths capable of detecting and controlling RF signals across the entire 25 MHz bandwidth of the uplink and downlink channels. In contrast, the down-converter 40 is designed to detect individual desired RF signals within the wide bandwidth paths 36 and 38. In particular, the down-converter 40 operates to detect the presence (and power level) of an RF signal within a narrow pass-band (of, for example, about 30 KHz bandwidth) centered on an Intermediate Frequency (IF). As is known in the art, the IF can be obtained by mixing the synthesizer signal and a sample of RF signals within a selected one of the wide band paths 36 and 38. By tuning the synthesizer 104 to various frequencies in succession, the micro controller 42 can scan the entire 25 MHz bandwidth for each channel to detect weak desired RF signals. The speed at which the micro-controller 42 can scan an entire channel (e.g. 25 MHz band-width) will vary with the bandwidth of the selectable BPF 100. A larger bandwidth of the selectable BPF 100 increases the scanning speed, and thus allows the micro-controller 42 to isolate discrete RF signals faster. In most cases, this increased processing speed is obtained at a cost of reduced sensitivity to weak signals. However, by dynamically switching the selectable filter 100 from a wide to a narrow bandwidth and thereby restricting the detection to a narrow band centered on the intermediate frequency (e.g. by reducing the bandwidth of the selectable BPF 100), the down-converter 40 and micro controller 42 can detect weak desired RF signals that are embedded in noise.

[0080] More particularly, the down-converter 40 and micro controller 42 cooperate to implement a digital offset correction technique in which the gain of a wide-band AGC is set for RF signals that may not have captured the AGCs. As is known in the art, a wide-band AGC will normally level to the highest signal that captures the AGC within a defined bandwidth. If no signals are present, an AGC may level to the thermal and system noise of a given bandwidth. If weak desired (i.e., uplink or downlink RF) signals are present, and

the AGC bandwidth is much larger than the signal bandwidth (such that noise masks the weak signals) a conventional AGC will tend to be captured by the noise rather than the weak desired signal. In the present invention, the narrow-band detection capability of the down-converter 40 is used to detect the (weak) desired signals embedded in the noise. Detection of the desired uplink and downlink signals is then used by the micro controller 42 to offset the output to which the respective AGCs 44 and 66 level. This same technique can also be used to detect weak and moderate desired signals in the presence of high-level unwanted signals that would otherwise capture an AGC and limit the system gain for the desired signals.

[0081] In operation, a minimum acceptable uplink channel RF signal power of the WCD 6 can be negotiated at a start of a communications session. This uplink channel RF signal power is then maintained substantially constant by the WCD 6 (during the communications session), because the IGC 30 adapts to changes in the position of the WCD 6 by controlling the downlink channel ERP to hold the downlink power received by the WCD 6 substantially constant (during the communications session). The IGC 30 accomplishes this by accepting widely varying uplink channel RF signal powers from the WCD 6, and then using changes in the received uplink signal power as an estimate of corresponding changes in the propagation loss (and hence changing distance) between the WCD 6 and the SCA 24. This information is used to calculate a change in the downlink channel ERP required to overcome the propagation loss change, and so maintain substantially constant downlink channel RF signal power at the WCD 6. With this arrangement, the APR can accommodate variations in received uplink channel RF signal power as high as 50 to 60 dB, depending largely on the proximity of the WCD 6 to the SCA 24.

[0082] As described above, the received uplink channel RF signal power level can be measured by the down-converter 40, and used by the micro controller 42 to control the downlink channel ERP. For example, if the received power of the uplink RF signals is greater than a predetermined minimum threshold, then the downlink RF signal transmit power can be reduced (i.e., the coverage area of the repeater reduced) by an amount proportional to the difference between the received power and the threshold, in order to improve spectrum efficiency, conserve energy, increase reliability and reduce system gain. Conversely, if the measured power of the received uplink RF signals drops below the predetermined minimum threshold, then the downlink channel ERP can be increased (i.e., the coverage area of the repeater expanded) by an amount proportional to the difference between the received power and the threshold to improve the signal-to-noise ratio.

[0083] If desired, the ACA can select the value of the threshold based on any of a variety of signal evaluation techniques. For example, the threshold could be selected based on an initially detected uplink RF signal power received from the WCD 6 at the start of a communications session (or when the WCD 6 starts transmitting uplink RF signal traffic). Alternatively, the threshold may be selected based on a detected format of the uplink RF signals. For example, by controlling the bandwidth of the selectable BPF 100 and monitoring the detection signal output by the detector 102, the micro controller 42 can detect changes in the RF signals in each of the paths 36 and 38. These changes

can be used to identify the format of the RF signals being used by the subscriber's WCD 6. In particular, periodic pulse-like changes in the signal level in the uplink path 37 (independent of selectable BPF 100 bandwidth) indicates that the WCD 6 is using a narrow-band pulsed (e.g., Time Division Multiple Access (TDMA)) signal format. Changes in power level due to changes in the bandwidth of the selectable BPF 100 indicates that the WCD 6 is using a broad-band (e.g., Code Division Multiple Access (CDMA)) signal format. If neither of these types of changes are detected, then the WCD 6 is using a narrowband continuous (e.g., Advanced Mobile Phone Service (AMPS)) signal format. Once the signal format is known, the ACA can select an appropriate threshold value (e.g., from among a set of predetermined threshold values) for optimizing the system performance.

[0084] Thus it will be seen that the present invention provides a system capable of adaptively controlling the coverage area of an on-frequency repeater. RF signals received from a transceiver (e.g. a base station of a subscriber's wireless communications device) are detected using a broadband detector, narrowband down converter and detector, and these detected signals are monitored by the micro controller. The micro controller operates, under control of suitable software implementing an Adaptive Control Algorithm, to adjust the ERP of RF signals transmitted to the transceiver to thereby control the coverage area of the repeater, and maintain a substantially constant power level of RF signals received by the transceiver.

[0085] The embodiment(s) of the invention described above is (are) intended to be exemplary only. The scope of the invention is therefore intended to be limited solely by the scope of the appended claims.

We claim:

1. A method of adaptively controlling a coverage area of a transceiver of a wireless communications network, the method comprising steps of:

detecting a power level of a first RF signal received from a second transceiver of the wireless communications network; and

controlling an effective radiated power (ERP) of a second RF signal transmitted to the second transceiver, using the detected power level, so as to maintain a substantially constant power level of the second RF signal received by the second transceiver.

2. A method as claimed in claim 1, wherein the second transceiver is either one of a base station and a subscriber's wireless communications device.

3. A method as claimed in claim 1, wherein the step of detecting the power level of the first RF signal comprises steps of:

detecting the first RF signal within a wide bandwidth signal path of the transceiver; and

comparing the detected power level to the predetermined threshold.

4. A method as claimed in claim 3, wherein the step of comparing the detected power level to the predetermined threshold comprises a step of calculating a difference between the detected power level and the predetermined threshold.

5. A method as claimed in claim 4, wherein the predetermined threshold comprises an initial power level of the first RF signal.

6. A method as claimed in claim 4, wherein the predetermined threshold is based on a format of the first RF signal.

7. A method as claimed in claim 6, further comprising steps of:

analyzing the first RF signal to determine the format of the first RF signal; and

selecting the threshold from among a set of predetermined threshold values, based the determined format.

8. A method as claimed in claim 1, wherein the step of controlling the effective radiated power (ERP) of the second RF signal comprises steps of:

estimating a variation in propagation loss between the transceivers based on the comparison result;

estimating a variation in the ERP of the second RF signal required to compensate the estimated propagation loss variation; and

adjusting the ERP of the second RF signal in accordance with the estimated ERP variation.

9. A method as claimed in claim 8, wherein the step of adjusting the ERP of the second RF signal comprises a step of adjusting a total gain of a wide bandwidth signal path conveying the second RF signal.

10. A system for adaptively controlling a coverage area of a transceiver of a wireless communications network, the system comprising:

a detector adapted to detect a power level of a first RF signal received from a second transceiver of the wireless communications network; and

a controller adapted to control an effective radiated power (ERP) of a second RF signal transmitted to the second transceiver, using the detected power level, so as to maintain a substantially constant power level of the second RF signal received by the second transceiver.

11. A system as claimed in claim 10, wherein the second transceiver is any one of a base station, a repeater and a subscriber's wireless communications device.

12. A system as claimed in claim 10, wherein the detector comprises at least a narrow-band detector adapted to detect the first RF signal within a respective first wideband signal path of the transceiver.

13. A system as claimed in claim 10, wherein the controller comprises:

a processor; and

a variable gain amplifier responsive to a control signal from the processor to control the ERP of the second RF signal by adjusting gain of a respective second wideband signal path conveying the second RF signal through the transceiver.

14. A system as claimed in claim 13, wherein the processor is adapted to compare the detected power level to a predetermined threshold.

15. A system as claimed in claim 14, wherein the predetermined threshold comprises an initial power level of the first RF signal.

16. A system as claimed in claim 14, wherein the predetermined threshold is based on a format of the first RF signal.

17. A system as claimed in claim 16, wherein the processor is further adapted to:

analyze the first RF signal to determine the format of the first RF signal; and

select the threshold from among a set of predetermined threshold values, based the determined format.

18. A system as claimed in claim 13, wherein the processor is further adapted to:

estimate a variation in propagation loss between the transceivers based on the comparison result;

estimate a variation in the ERP of the second RF signal required to compensate the estimated propagation loss variation; and

generate the control signal to control the variable gain amplifier in accordance with the estimated ERP variation.

* * * * *