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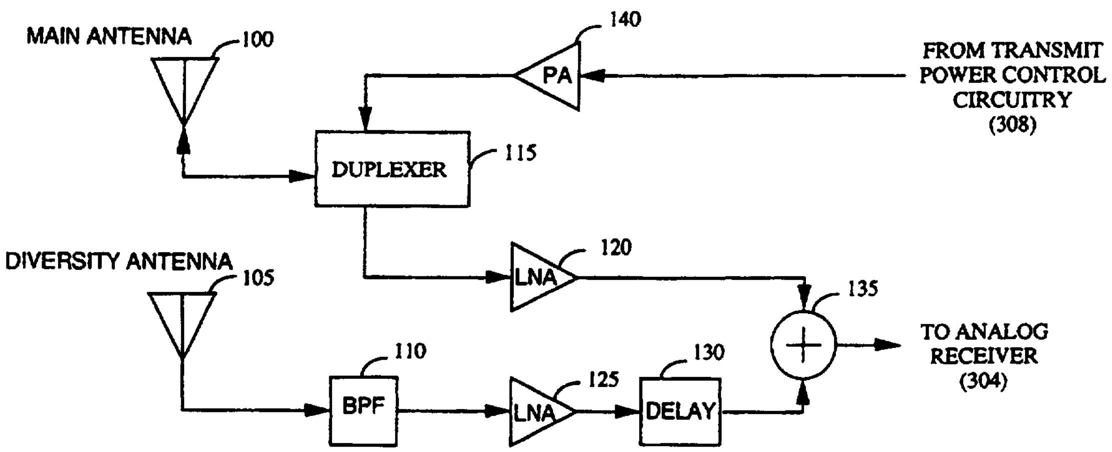

(57) Abstract

A diversity antenna system in a mobile unit which provides time, space and antenna pattern diversity to mitigate the effects of fading at a CDMA mobile unit. The system is comprised of a diversity antenna (105) and a main antenna (100). The main antenna (100) and diversity antenna (105) are physically separated and oriented such that they have different antenna gain patterns. In a first embodiment, the diversity antenna (105) functions as a receive antenna only, while the main antenna (100) performs both transmit and receive functions. In a second embodiment, both the main antenna (100) and the diversity antenna (105) transmit and receive signals. A delay circuit (130) couples the diversity antenna (105) to a summer (135) which sums the signals received by the main antenna (100) and the diversity antenna (105), respectively.

METHOD AND APPARATUS FOR PROVIDING ANTENNA DIVERSITY IN A PORTABLE RADIOTELEPHONE

BACKGROUND OF THE INVENTION

I. Field of the Invention

The present invention relates to communication systems, particularly wireless communication systems including cellular telephones, personal communication services (PCS), wireless private branch exchange (PBX) and wireless local loop telephone systems. More specifically, the present invention relates to a novel and improved distributed antenna system for cellular and microcellular communication systems to facilitate reliable signal reception in a terrestrial environment.

II. Description of the Related Art

The use of code division multiple access (CDMA) modulation techniques is one of several techniques for facilitating communications in which a large number of system users are present. Other multiple access communication system techniques, such as frequency hopping spread spectrum, time division multiple access (TDMA), frequency division multiple access (FDMA) and amplitude modulation (AM) schemes such as amplitude companded single sideband (ACSSB) are known in the art. However, the spread spectrum modulation technique of CDMA has significant advantages over these modulation techniques for multiple access communication systems. The use of CDMA techniques in a multiple access communication system is disclosed in U.S. Patent No. 4,901,307, entitled "SPREAD SPECTRUM MULTIPLE ACCESS COMMUNICATION SYSTEM USING SATELLITE OR TERRESTRIAL REPEATERS", assigned to the assignee of the present invention, and is incorporated herein by reference.

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

The terrestrial channel experiences signal fading that is characterized by Rayleigh fading. The Rayleigh fading characteristic in the terrestrial channel signal is caused by the signal being reflected from many different features of the physical environment. As a result, a signal arrives at a mobile unit receiver from many directions with different transmission delays. At the UHF frequency bands usually employed for mobile radio communications, including those of cellular mobile telephone systems, significant phase differences in signals traveling on different paths may occur. The possibility for destructive summation of the signals may result, with occasional deep fades occurring.

Terrestrial channel fading is a very strong function of the physical position of the mobile unit. A small change in position of the mobile unit changes the physical delays of all the signal propagation paths, which further results in a different phase for each path. Thus, the motion of the mobile unit through the environment can result in a quite rapid fading process. For example, in the 850 Mhz cellular radio frequency band, this fading can typically be as fast as one fade per second per mile per hour of vehicle speed. Fading this severe can be extremely disruptive to signals in the terrestrial channel resulting in poor communication quality. The problem of fading at the mobile unit is further exacerbated by the user's head or hand interfering with the antenna pattern and gain.

The direct sequence spread spectrum CDMA modulation techniques disclosed in U.S. Patent No. 4,901,307 offer many advantages over narrow band modulation techniques used in communication systems employing satellite or terrestrial repeaters. The terrestrial channel poses special problems to any communication system particularly with respect to multipath signals. The use of CDMA techniques permit the special problems of the terrestrial channel to be overcome by mitigating the adverse effect of multipath, e.g. fading, while also exploiting the advantages thereof.

In a CDMA communication system, the same wideband frequency channel can be used for communication by all base stations. Typically, a frequency division scheme is used where one frequency band is used for communications from the base stations to the remote or mobile stations (forward link) and another for communications from the remote or mobile stations to the base stations (reverse link). The CDMA waveform properties that provide processing gain are also used to discriminate between signals that occupy the same frequency band. Furthermore the high speed pseudo noise (PN) modulation allows many different propagation paths to be separated, provided the difference in path delays exceed the PN chip duration, i.e. 1/bandwidth. If a PN chip rate of approximately 1 Mhz is employed in a CDMA system, the full spread spectrum processing gain, equal to the ratio of the spread bandwidth to system data rate, can be employed to discriminate against paths that differ by more than one microsecond in path delay from each other. A one microsecond path delay differential corresponds to differential path distance of approximately 1,000 feet. The urban environment typically provides differential path delays in excess of one microsecond, and up to 10-20 microseconds are reported in some areas.

In narrow band modulation systems such as the analog FM modulation employed by conventional telephone systems, the existence of multiple paths results in severe multipath fading. With wideband CDMA modulation, however, the different paths may be discriminated against in the demodulation process. This discrimination greatly reduces the severity of multipath fading. Multipath fading is not totally eliminated in using CDMA discrimination techniques because there occasionally are paths with delayed differentials of less than the PN chip duration for the particular system. Signals having path delays on this order cannot be discriminated against in the demodulator, resulting in some degree of fading.

It is therefore desirable in the such communication systems that some form of diversity be provided which would permit a system to reduce fading. Diversity is one approach for mitigating the deleterious effects of fading. Three major types of diversity exist: time diversity, frequency diversity, and space diversity.

Time diversity can best be obtained by the use of repetition, time interleaving, and error detection and correction coding which is a form of repetition. CDMA by its inherent nature of being a wideband signal offers a form of frequency diversity by spreading the signal energy over a wide bandwidth. Therefore, frequency selective fading affects only a small part of the CDMA signal bandwidth. Space or path diversity may be obtained by providing multiple signal paths through simultaneous links to or from a mobile user through two or more base stations. Furthermore, path diversity may be obtained by exploiting the multipath environment through spread spectrum processing by allowing signals arriving with different propagation delays to be received and processed separately. A CDMA communication system wherein the cell-sites employ each of the above-described types of diversity is described in U. S. Patent No. 5,280,472, entitled "CDMA

MICROCELLULAR TELEPHONE SYSTEM AND DISTRIBUTED ANTENNA SYSTEM THEREFOR", which is assigned to the assignee of the present invention and is incorporated herein by reference. In the just-mentioned patent, diversity is exploited by the provision of a "rake" receiver architecture in which multiple receivers are provided, each capable of receiving a signal that has traveled a different path and therefore exhibits a different delay.

One way to achieve diversity is the use of collocated antennas as described in above mentioned U. S. Patent No. 5,280,472. In the just mentioned patent, a communication system is disclosed which uses collocated antennas at the cell-site base station to provide diversity. One way in which this is done is to place the antennas some distance apart. The distance should allow the two antennas to have substantially the same coverage area while being spaced apart enough to provide independent fading. However, due to the relatively small size of a mobile unit, the collocated antennas may be too close together to provide adequate independence in fading characteristics based on physical separation distance alone. A more advantageous way to achieve receive diversity in a mobile unit is to provide each antenna of a set of collocated antennas with a different polarization, such as vertical and horizontal polarization.

A standard terrestrial environment contains many objects with radio-reflective surfaces oriented at many different angles. These include both man-made structures such as buildings, and natural land features such as hills and valleys. Thus, a mobile unit within the terrestrial environment has a variety of signal paths to and from a fixed antenna located at a cell site. This variety of signal paths involves multiple reflections from the reflective surfaces of the objects in the terrestrial environment. Depending on the angles involved, each reflection of a signal may rotate the polarization of the reflected signal. Therefore two signals having different polarization reflecting from the same set of surfaces form two signal paths having different phase characteristics. Because the signals have different phase characteristics, they also have different fading characteristics. Due to this process, two collocated antennas where the antennas have two different polarizations possess a high degree of independence in fading even if the antennas are placed very close to one another.

Another method of diversity exploited in the above-mentioned U.S. Patent No. 5,280,472 is path diversity. In path diversity, the signal is radiated from multiple antennas, providing more than one propagation path. If two or more antennas can provide acceptable communication paths to the mobile unit receiver then fading mitigation through path diversity can be obtained. Similarly, the reverse link communication paths can be enhanced by exploiting path diversity.

The above mentioned patents and patent applications disclose a novel multiple access technique wherein a large number of mobile unit telephone system users communicate through satellite repeaters or terrestrial base stations using code division multiple access spread spectrum modulation that allows the spectrum to be used multiple times. The resulting system design has a much higher spectral efficiency than can be achieved using previous multiple access techniques.

SUMMARY OF THE INVENTION

The present invention encompasses a diversity antenna system in a mobile unit which provides time, space and antenna pattern diversity to mitigate the effects of fading at the mobile unit. The system is comprised of a plurality of antennas. The plurality of antennas are comprised of a diversity antenna and a main antenna. The main antenna and diversity antenna are physically separated and oriented such that they have very different antenna gain patterns. In a first embodiment, the diversity antenna functions as a receive antenna only, while the main antenna performs both transmit and receive functions. In a second embodiment, both the main antenna and the diversity antenna transmit and receive signals. A delay circuit couples the diversity antenna to a summer which sums the signals received by the main antenna and the diversity antenna, respectively.

Summing the main and diversity signals provides space diversity due to the physical separation distance of the two antennas. It also provides antenna pattern diversity when the main and diversity antennas are oriented in such a way that their pattern/gain is very different, or when they are differently polarized. Introducing a delay in the diversity signal before it is summed with the main signal provides time diversity so that the two signals can be discriminated by the rake receiver of the mobile unit.

The output of the summer is presented to the standard receive circuitry of a CDMA mobile unit. A rake receiver decomposes the signal into its component main and diversity signals. A diversity combiner and decoder then time-aligns the signal components, adds them together, and decodes the resultant signal. In this way, the main and diversity signals are processed in exactly the same manner by the existing mobile unit receive circuitry as would be any other combination of signals caused by multiple reception paths. By using the existing mobile unit receive circuitry to process the summed signal of the present invention, the additional size, cost, and weight of multiple receive chains can be avoided, while still taking advantage of the various forms of diversity accomplished by providing a diversity antenna. Another disadvantage overcome by using the present invention with the existing RF circuitry of the CDMA mobile units is that one can avoid the losses inherent in using a switch to select between multiple receive paths, each coupled to an independent antenna.

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 illustrates a first embodiment of the diversity antenna system of the present invention.

FIG. 2 illustrates a second embodiment of the diversity antenna system of the present invention.

FIG. 3 illustrates a CDMA mobile unit which is capable of being used with the diversity antenna system of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

A first embodiment, illustrated in FIG. 1, utilizes a main antenna **100** for both transmitting and receiving signals, and a diversity antenna **105** for receiving only. Main antenna **100** is coupled to a duplexer **115**. Duplexer **115** couples both the transmit and receive circuitry to main antenna **100**. The transmit circuitry is coupled to duplexer **115** by a power amplifier **140**. The receive output of duplexer **115** is coupled to a summer **135** by a first low noise amplifier **120**.

The signals received on diversity antenna **105** are bandpass filtered **110** to eliminate spurious received signals outside of the desired receive bandwidth, and then amplified by a second low noise amplifier **125**. A delay **130** is introduced between second low noise amplifier **125**. Delay **130** provides the time diversity required so that signals received on diversity antenna **105** can be discriminated from those received on main antenna **100** by the rake receiver in the receive circuitry, which will be discussed later (see

FIG. 2). In the preferred embodiment, this delay is between 5-10 μs in order to provide adequate time diversity for proper reception at the rake receiver, without interfering with large signals reflected from main antenna **100**. After being delayed **130**, the signal received on diversity antenna **105** is provided to summer **135** which sums the signal received on diversity antenna **105** with the signal received on main antenna **100**.

A second embodiment of the diversity antenna technique of the present invention as used in the mobile unit is illustrated in FIG. 2. In contrast to the first embodiment illustrated in FIG. 1, this second embodiment uses a diversity antenna **205**, in addition to a main antenna **200**, for both transmitting and receiving signals. Similarly to the first embodiment of FIG. 1, duplexer **220** couples both the transmit and receive circuitry to main antenna **200**. However, in this second embodiment, duplexer **220** also couples both the transmit and receive circuitry to diversity antenna **205**.

Main antenna **200** is coupled to duplexer **220** through a summer **235**. Diversity antenna **205** is coupled to duplexer **220** through both delay **230** and summer **235**. As in the first embodiment of FIG. 1, delay **230** introduces a time delay in the signal received by diversity antenna **205**, providing the time diversity required so that signals received on diversity antenna **205** can be discriminated from those received on main antenna **200** by the rake receiver in the mobile unit receive circuitry. Signals received by main antenna **200** and diversity antenna **205** are summed by summer **235** before being input to duplexer **220**. The transmit input of duplexer **220** is coupled to the transmit circuitry of the mobile unit through a power amplifier **240**. The receive input of duplexer **220** is coupled to the receive circuitry of the mobile unit through a low noise amplifier **250**.

The second embodiment of FIG. 2 differs from the first embodiment of FIG. 1 in that when the mobile unit is transmitting, both a main and a delayed diversity signal are transmitted by the mobile unit. This second embodiment provides both time and space diversity on the reverse link. A CDMA base station capable of exploiting this time and space diversity provided by the mobile unit is described in above-mentioned U. S. Patent 5,280,472.

In both of the above embodiments, main antennas **100** and **200** and diversity antennas **105** and **205** being physically separate antennas, provide space diversity in reception. A signal on the forward link from the cell site to the mobile unit may experience a fade at either one of main antennas **100** and **200** or diversity antennas **105** and **205**. However, because the path length on the forward link is physically different for main antennas **100** and **200** and diversity antennas **105** and **205**, it is very unlikely that both antennas in either embodiment will experience a fade at the same time. Additionally, The diversity antennas **105** and **205** in each of the above embodiments can be polarized or physically oriented in the mobile unit such that their gain pattern is very different from that of the main antennas **100** and **200**. One such approach is to mount the diversity antennas **105** and **205** orthogonally from the main antennas **105** and **205**. In this case, polarization loss due to the orientation of the mobile in the operating position may be reduced. Another approach would be to use two different types of antennas, for example a loop antenna and a rod antenna. In such a case, the loop antenna would have a different antenna pattern than the rod antenna.

The presence of a diversity antenna **105** and **205** in each of the above embodiments decreases the overall noise figure of the receive chain of the mobile unit over what it would be if there were no diversity antenna present. Additionally, in the second embodiment, where diversity antenna **205** is transmitting as well as receiving, the presence of diversity antenna **205** decreases the overall transmit power of the mobile unit. These factors present a tradeoff between antenna diversity and antenna-related losses in the design of the mobile unit. To address this tradeoff, each of the embodiments of the present invention may sum the diversity signal with a different weight than the main signal in its respective summer **135** and **235**. This is particularly useful in the second embodiment, where diversity antenna **205** is transmitting as well as receiving. For example, if a 3 dB loss in noise figure and transmit power is not desired, the signal received by diversity antenna **205** may be summed with a lower weight in summer **235** than the signal received by main antenna **200**. In this case, the diversity benefit provided by diversity antenna **205** would be less than is theoretically possible, however it may still provide acceptable performance. For instance, nulls as deep as 20 to 30 dB in the antenna pattern are very common while the mobile is operating near the user's head. If the diversity signal were summed in at 10 dB lower than the main signal, the null depth could be limited to approximately 10 dB, without a significant noise figure or transmit power loss due to the presence of diversity antenna **205**.

In each of the above embodiments, time diversity is provided by time-delaying the diversity signals in delays **130** and **230** before summing them with the main signals in summers **135** and **235**. This time diversity is possible because of the nature of the orthogonal PN sequences used in the CDMA waveform. As described below, the resultant summed signal produced by summers **135** and **235** can be processed by separating the main and diversity signals, time aligning them, and then re-combining them.

It should be noted that alternate embodiments could perform the summing function at any point in the receive path prior to the rake receiver. For example, one advantage of performing the summing function after downconversion (at IF) is that the time delay is easier to implement at IF than at RF. However, there would be an associated tradeoff with regard to the duplication of circuitry in the diversity receive path prior to the summing point.

FIG. 3 illustrates, in block diagram form, a CDMA mobile unit capable of use with the diversity antenna technique of the present invention. Receiver **304** receives the RF frequency signals from the receive path of either of the above embodiments for amplification and frequency downconversion. The signals are also filtered and digitized for providing to digital data receivers **310A** - **310N** along with searcher receiver **314**. Further details of receivers **304, 310A** - **310N** and **314** are illustrated in U.S. Patent No. 5,103,459, entitled "SYSTEM AND METHOD FOR GENERATING SIGNAL WAVEFORMS IN A CDMA CELLULAR MOBILE TELEPHONE SYSTEM", and U.S. Patent No. 5,109,390, entitled "DIVERSITY RECEIVER IN A CDMA CELLULAR TELEPHONE SYSTEM", both assigned to the assignee of the present invention.

Receiver **304** also performs a power control function for adjusting the transmit power of the mobile unit. Receiver **304** generates an analog power control signal that is provided to transmit power control circuitry **308**.

The digitized signal at the output of analog receiver **304** contains the main and time-delayed diversity signals of the above embodiments, and may also contain the signals of many on-going calls together with the pilot carriers transmitted by the current base station and all neighboring base stations. The function of the receivers **310A** - **310N** is to correlate these digitized signals with the proper PN sequence. This correlation process provides a property that is well-known in the art as "processing gain" that enhances the signal-to-interference ratio of a signal matching the proper PN sequence while not enhancing other signals. Correlation output is then synchronously detected using the pilot carrier from the closest base station as a carrier phase reference. The result of this detection process is a sequence of encoded data symbols.

A property of the PN sequence as used in the present invention is that discrimination is provided among diversity signals, including those caused by multipath transmission in the terrestrial environment as well as the time-delayed diversity signals of the present invention. When the signal arrives at the mobile receiver after passing through more than one path, or in the present invention through more than one antenna, there is a difference in the reception time of the signal. If this time difference exceeds one chip duration, then the correlation process discriminates between the signals. The data receiver can track and demodulate either of the earlier or later arriving signal. If two or more data receivers, typically three, are provided then multiple independent paths can be tracked and processed in parallel.

Searcher receiver **314**, under control of control processor **316** is for continuously scanning the time domain around the nominal time of a received pilot signal of the base station for other multipath pilot signals. Receiver **314** measures the strength of any reception of a desired waveform at times other than the nominal time. Receiver **314** compares signal strength in the received signals. Receiver **314** provides a signal strength signal to control processor **316** indicative of the strongest signals. Processor **316** provides control signals to data receivers **310A** - **310N** for each to process a different one of the strongest signals.

The outputs of receivers **310A** - **310N** are provided to diversity combiner and decoder circuitry **318**. The diversity combiner circuitry contained within circuitry **318** adjusts the timing of the two streams of received symbols into alignment and adds them together. This addition process may be proceeded by multiplying the two streams by a number corresponding to the relative signal strengths of the two streams. This operation can be considered a maximal ratio diversity combiner. The resulting combined signal stream is then decoded using a forward error correction (FEC) decoder also contained within circuitry **318**. The usual digital baseband equipment is a digital vocoder system. The CDMA system is designed to accommodate a variety of different vocoder designs.

Baseband circuitry **320** typically includes a digital vocoder (not shown) that may be a variable rate type. Baseband circuitry **320** further serves as an interface with a handset or any other type of peripheral device. Baseband circuitry **320** provides output information signals to the user in accordance with the information provided thereto from circuitry **318**.

In the mobile unit-to-base station link (reverse link), user analog voice signals are typically provided through a handset as an input to baseband circuitry **320**. Baseband circuitry **320** includes an analog to digital (A/D) converter (not shown) that converts the analog signal to digital form. The digital signal is provided to the digital vocoder where it is encoded. The vocoder output is provided to a forward error correction (FEC) encoding circuit (not shown). In the preferred embodiment, the error correction encoding implemented is of a convolutional encoding scheme. The digitized encoded signal is output from baseband circuitry **320** to transmit modulator **322**.

Transmit modulator **322** encodes the transmit data, that in the preferred embodiment is a 64-ary orthogonal signaling technique based upon Walsh codes, and then modulates the encoded signal on a PN carrier signal whose PN sequence is common amongst all mobile units, but is of a different code phase offset assigned to the mobile station for the call. In the alternative the PN sequence may be chosen according to the assigned address function for the call. The PN sequence is determined by control processor **316** from call setup information that is transmitted by the base station and decoded by receivers **310A** - **310N** and control processor **316**. Control processor **316** provides the PN sequence information to transmit modulator **322** and to receivers **310A** - **310N** for call decoding. As a further detail an outer PN code may be used upon the PN spread signal. Further details on data modulation are disclosed in the above-mentioned U.S. Patent No. 5,103,459.

Transmit modulator **322** further converts the modulated signal to analog form for modulating upon an IF carrier. The IF signal output from transmit modulator **322** is provided to transmit power control circuitry **308**. In circuitry **308** transmission signal power is controlled by the analog power control signal provided from receiver **304**. Control bits transmitted by the base station in the form of power adjustment commands are processed by data receivers **310A** - **310N** and provided to control processor **316**. These power adjustment commands are used by control processor **316** in setting the power level in mobile unit transmission. In response to these commands, control processor **316** generates a digital power control signal that is provided to circuitry **308**. Further information on the relationship of receivers **310A** - **310N** and **314**, control processor **316** and transmit power control **308** with respect to power control is available in U.S. Patent No. 5,056,109, entitled "METHOD AND APPARATUS FOR CONTROLLING TRANSMISSION POWER IN A CDMA CELLULAR MOBILE TELEPHONE SYSTEM", assigned to the assignee of the present invention. Transmit power control circuitry **308** outputs the power controlled modulated signal to the transmit power amplifier circuitry **140** and **240** of the present invention.

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.

I CLAIM:

CLAIMS

1. A diversity antenna system in a mobile radio, said mobile radio operating in a wireless communication environment comprising at least one base station which transmits communication signals, said diversity antenna system comprising:

a main antenna for transmitting radio signals and receiving said communication signals, said main antenna providing a main antenna signal in response to said received communication signals;

at least one diversity antenna for receiving said communication signals, said at least one diversity antenna providing a diversity antenna signal in response to said received communication signals;

a delay circuit, coupled to said at least one diversity antenna, for time-delaying said diversity antenna signal; and

a summer, having a summer main input coupled to said main antenna and a summer diversity input coupled to said delay circuit and having a summer output, said summer for generating a sum signal in response to the sum of said main antenna signal and said diversity antenna signal.

2. The diversity antenna system of claim 1 further comprising a duplexer, coupled to said main antenna and said summer main input and interposed therebetween, for receiving said main antenna signal and providing said radio signals to said main antenna.

3. The diversity antenna system of claim 2 further comprising:

a first low-noise amplifier, coupled to said duplexer and said main input of said summer and interposed therebetween, for amplifying said main antenna signal; and

a second low-noise amplifier, coupled to said diversity antenna and said delay circuit and interposed therebetween, for amplifying said diversity antenna signal.

4. The diversity antenna system of claim 3 further comprising a bandpass filter, coupled to said diversity antenna and said second low noise amplifier and interposed therebetween, for enhancing the spectral purity of said diversity antenna signal.

5. The diversity antenna system of claim 1 wherein said at least one diversity antenna is mounted in said mobile radio orthogonally to said main antenna.

6. The diversity antenna system of claim 1 further comprising a duplexer, coupled to said summer output, for receiving said sum signal and providing said radio signals to said main antenna and said at least one diversity antenna.

7. A diversity antenna system in a mobile radio having a receive circuit and a transmit circuit, the system comprising:

a main antenna for receiving and transmitting radio signals;

a diversity antenna for receiving and transmitting radio signals;

a delay circuit, coupled to said diversity antenna, for time-delaying radio signals received and transmitted by said diversity antenna;

a combining circuit, coupled to said main antenna and said delay circuit, for summing radio signals received by said main antenna and received radio signals delayed by said delay circuit; and

a duplexer having an input/output coupled to said combining circuit, an input coupled to said transmit circuit, and an output coupled to said receive circuit.

8. The diversity antenna system of claim 7 wherein said diversity antenna is mounted in said mobile radio orthogonally to said main antenna.

9. A method for providing a diversity reception in a mobile radio having a main antenna and at least one diversity antenna, said mobile radio operating in a wireless communication environment comprising at least one base station which transmits radio signals, said method comprising the steps of:

receiving said radio signals on said main antenna;

receiving said radio signals on said at least one diversity antenna;

time-delaying said radio signals received by said at least one diversity antenna; and

summing said radio signals received by said main antenna with said time-delayed radio signals.

10. The method of claim 9 further comprising the steps of:

amplifying said radio signals received by said main antenna prior to summing said radio signals received by said main antenna with said time-delayed radio signals; and

amplifying said radio signals received by said diversity antenna prior to summing said radio signals received by said main antenna with said time-delayed radio signals.

11. The method of claim 10 further comprising the step of bandpass filtering said radio signals received by said diversity antenna.

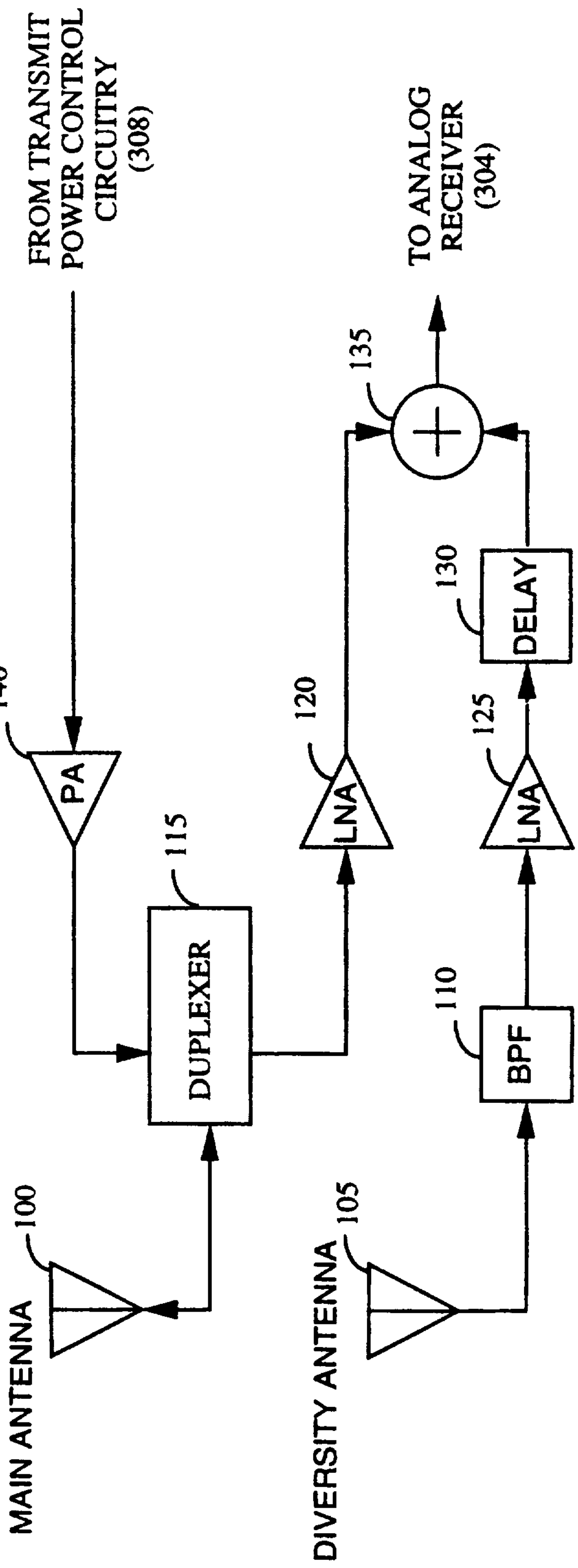
FROM TRANSMIT POWER CONTROL CIRCUITRY (308)
TO ANALOG RECEIVER (304)
135
140
PA
120
LNA
130
DELAY
125
LNA
115
DUPLEXER
110
BPF
100
MAIN ANTENNA
105
DIVERSITY ANTENNA

FIG. 1

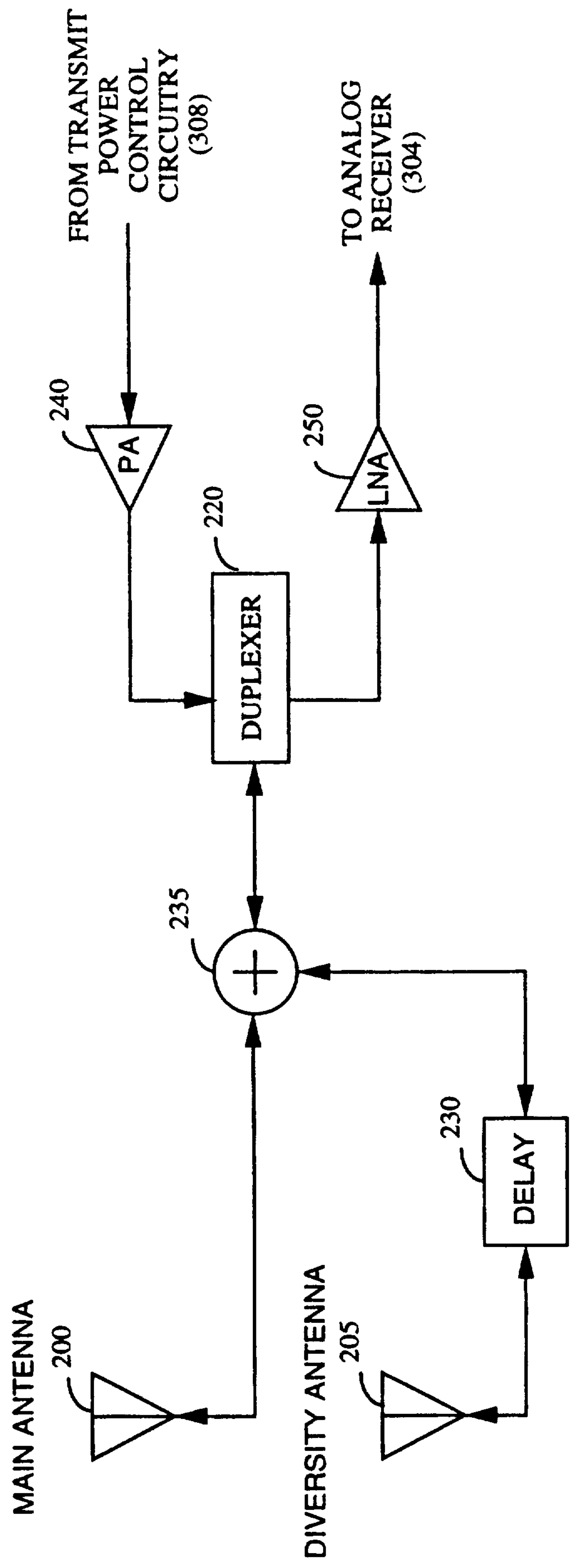
FROM TRANSMIT POWER CONTROL CIRCUITRY (308)
TO ANALOG RECEIVER (304)
240
PA
250
LNA
220
DUPLEXER
235
230
DELAY
MAIN ANTENNA
200
DIVERSITY ANTENNA
205

FIG. 2

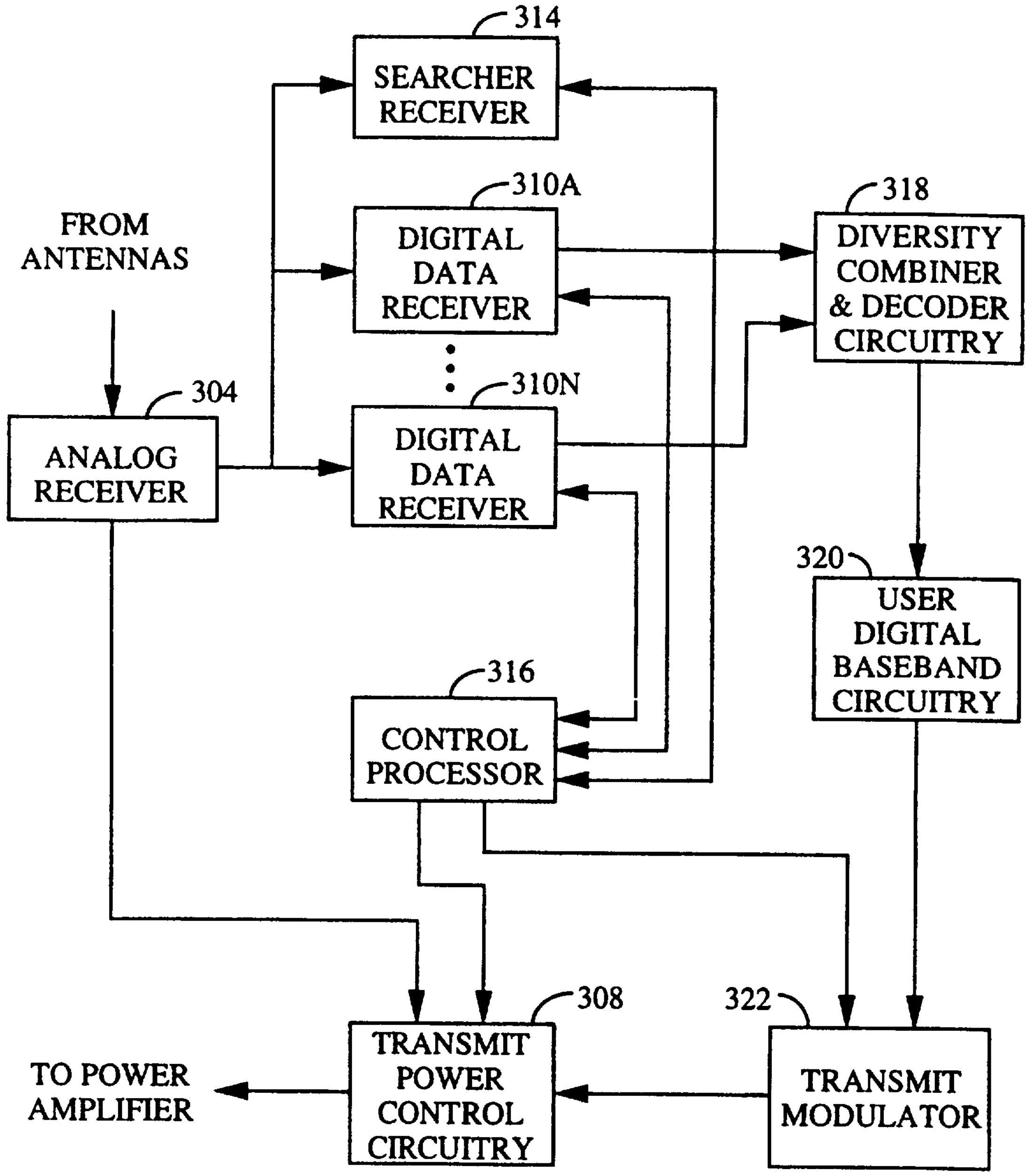
314
SEARCHER RECEIVER
310A
DIGITAL DATA RECEIVER
FROM ANTENNAS
318
DIVERSITY COMBINER & DECODER CIRCUITRY
304
ANALOG RECEIVER
310N
DIGITAL DATA RECEIVER
320
USER DIGITAL BASEBAND CIRCUITRY
316
CONTROL PROCESSOR
308
322
TO POWER AMPLIFIER
TRANSMIT POWER CONTROL CIRCUITRY
TRANSMIT MODULATOR

FIG. 3

INTERNATIONAL SEARCH REPORT

International Application No
PCT/US 96/20656

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 H04B7/08

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 H04B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5 422 908 A (SCHILLING DONALD L) 6 June 1995	1,9,10
Y	see column 1, line 29 - line 53 see column 2, line 7 - line 17 see column 3, line 1 - line 48; figures 1,2 see column 1, line 54 - line 63 see column 4, line 49 - column 5, line 18; figure 3 see column 5, line 47 - column 6, line 29 ---	2-4,6,7, 11

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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

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"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

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"&" document member of the same patent family

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Date of the actual completion of the international search	Date of mailing of the international search report
29 April 1997	29.05.97

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax (+31-70) 340-3016	Bossen, M

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INTERNATIONAL SEARCH REPORT

International Application No
PCT/US 96/20656

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	GB 2 259 430 A (MOTOROLA LTD) 10 March 1993 see page 2, line 3 - line 25 see page 4, line 1 - page 6, line 10; figures 1,2 see page 7, line 36 - line 37; claims 1,12,16 ---	1,9,10
Y	GB 2 237 706 A (RACAL RES LTD) 8 May 1991 see page 5, line 10 - page 10, line 20; figures 1-3 -----	2-4,6,7,11

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
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		CA 2076290 A	08-03-93
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		IT 1258477 B	26-02-96
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