



METHOD AND APPARATUS FOR OBTAINING TRANSMIT DIVERSITY USING SWITCHED ANTENNAS

BACKGROUND OF THE INVENTION

5 I Field of the Invention

The present invention relates generally to wireless radio telephone systems that use a transmitting station having at least two antennas for transmitting information to one or more receiving units served by the transmitting station. More particularly, the present invention relates to a
10 novel and improved method and apparatus for providing diversity transmissions to a receiving unit served by the transmitting station.

II. Description of the Related Art

It is well known in the art that the performance of the reverse link of
15 a wireless communications system can be improved by providing multiple transmission paths. With multiple transmissions paths, a diversity gain is obtained by combining the phase adjusted signals from the different paths when they are received. The combined signal is less likely to fade to an unexceptable level because deep fades in the combined signal occur only
20 when the fades in the individual paths are aligned with each other.

It is also possible to obtain signal diversity in the channel from the base to the mobile, i.e. in the forward link. However, obtaining signal diversity in the forward link is more difficult than obtaining it in the reverse link because mobile units must be as small and simple as possible.
25 Dual mobile receive antennas are commonly used in a mobile unit in some parts of the world. For example, in Japan, it is common to use dual receive antennas with the PDC system. Most of these antennas are switched (i.e., the signal is not received simultaneously by both antennas). This has the advantage of sharing the front end hardware. But does not result in as good
30 a reception as the case in which both antennas are receiving simultaneously. However, this approach increases the cost of the more numerous mobile receivers. There are several ways known in the prior art to obtain transmit diversity on the forward link with only one mobile receive antenna. One



consideration in providing transmit diversity in a code division multiple access (CDMA) communication link is the fact that each of the transmit channels preferably remain orthogonal to each of the other channels to reduce interference between channels. One CDMA system is described in
5 Electronics Industry Association standard TIA/EIA IS-95-A, entitled "Mobile Station-Base Station Compatibility Standard for Dual-Mode Wideband Spread Spectrum Cellular System". In a CDMA system, each channel is distinguished from each other channel by an orthogonal code, such as a Walsh code. For these codes to remain orthogonal, transmission path delays
10 need to be relatively equal for each of the channels transmitted over the forward link. Differences in the time of receipt of the multiple channels being transmitted over the forward link can be caused by the different channels being transmitted from different antennas or traversing different paths between the transmitter and receiver. In one case, the forward link
15 signal can be transmitted on multiple base station antennas using a different carrier frequency for each antenna. Since the signals are on different carrier frequencies, the received signals at the mobile do not interfere with one another. Additionally, different frequencies have different fading characteristics, especially if the frequencies are widely separated. This helps
20 to provide the different diversity paths. While this approach works, it requires enough bandwidth so that a different CDMA carrier frequency can be used on each transmit antenna.

In another prior art method, multiple delayed versions of the forward link signal can be transmitted on a single antenna and carrier frequency. If
25 the delayed versions are separated by enough time, the fading is different for the different versions. Therefore, time diversity is obtained. This method has the disadvantage that in a CDMA system, the multiple paths interfere with each other, since they are not orthogonal due to a misalignment of the Walsh codes of the undelayed signal with respect to the delayed signal.
30 Even when the base to mobile link only produces one resolvable path and a rake CDMA receiver with a finger on each delayed path is used, the receiver for each finger receives interference from the other delayed signal transmission.

The forward signal can also be transmitted on multiple base station antennas with the same carrier frequency using orthogonal waveforms. For example, in a CDMA system different Walsh codes can be used on the multiple antennas. If the transmit antennas are close to each other and the signals transmitted over the primary paths received from the multiple base station antennas are time aligned, the signals remain orthogonal. Thus, with small primary path time differences, a receiver for a finger of the rake does not receive interference from the other primary paths. However, when there is more than one path, each with different delays from a base station to the mobile, the paths will not be received as orthogonal to one another.

These problems and deficiencies are recognized and solved by the present invention in the manner described below.

SUMMARY OF THE INVENTION

The present invention provides diversity transmissions to a receiving station from a base station having at least first and second antennas by repeatedly switching one, several, or all of the code channels of the composite signal between the two antennas during the transmission, such that the switched code channels are transmitted alternately from the first and second antenna. In accordance with a preferred embodiment, all of the code channels from the base station are transmitted from the first antenna in the base station to the receiving units. After the start of the transmission of the information from the first antenna, transmission of the information from the first antenna to the receiving unit terminates and transmission of the message information from the second antenna in the base station to the receiving unit is initiated. After transmission of the message information from the second antenna is initiated, transmission of the message information from the second antenna to the receiving unit terminates and transmission of the message information from the first antenna in the base station to the receiving unit is initiated. This process of switching between the first and second antennas is repeated. Preferably, the switching occurs on Walsh code boundaries in order to maintain the orthogonality of the Walsh codes. If Walsh codes of varying lengths are used, then the switching

preferably occurs on the boundaries of the longest Walsh codes. Accordingly, Walsh codes are not split between the first and second antennas. Rather, a full Walsh code is transmitted from the first antenna before the transmit signal is switched to the second antenna. Likewise, a full
5 Walsh code is transmitted from the second antenna before the transmit signal is switched back to the first antenna. Assuming that the switching occurs relatively rapidly with respect to the size of a block of interleaved data, the switching results in diversity transmissions that improve the ability of a receiving unit to receive the coded and interleaved message
10 information that is transmitted from the base station. The interleaver disperses the encoded symbols in each antenna dwell period such that the decoder decisions are based on a mix of symbols from each antenna. Therefore, the decoder decisions are unreliable only when the mix of symbols from the different antennas, with different fading characteristics,
15 are unreliable over the span of symbols the decoder uses in its decision process.

BRIEF DESCRIPTION OF THE DRAWINGS

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

Figure 1 is a block diagram of a system for providing transmit

Figure 2 is a block diagram of a system in which the entire forward
25 link is switched between a first and second antenna.

Figure 3 is an illustration of the permissible switching times in accordance with one embodiment of the present invention.

Figure 4 is an illustration of the relationship between transmit signals transmitted from two base station antennas and received at a mobile unit.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring to the drawing, there is shown switched antenna diversity system 10 of the present invention. Switched antenna diversity system 10 provides transmit diversity by switching a transmit signal among multiple antennas, for example antennas 34, 36. In accordance with one embodiment a single code channel is switched. In accordance with another embodiment, several code channels of a forward link are switched together. In yet another embodiment, all of the code channels of a forward link are switched together (i.e., the entire forward link is switched). While only two antennas 34, 36 are shown in order to simplify the drawing, it will be understood that any number of antennas can be provided within diversity system 10, and that the method of switching the signal among the multiple antennas described herein can be applied to any number of antennas, assuming that the antennas are within a predetermined distance of one another which allows the received signals from these antennas to remain orthogonal upon receipt (i.e., that the difference in path delay from each antenna to the receiver is not too great). Additionally, while switched antenna diversity system 10 is described with respect to transmissions from a base station to a mobile unit, it will be understood that the method of the present invention can be applied to transmissions from any transmitting station to any receiving unit.

In accordance with a CDMA system which complies with TIA/EIA IS-95-A, a composite signal from a base station consists of multiple code channels where each code channel is intended for one or more receiving units. An information signal which is to be transmitted over one of several available Walsh channels is received by error-detection cyclic code redundancy check block 12 in a conventional manner, such as described in TIA/EIA IS-95-A. An error-correction encoder tail is added in block 14. Encoding and block interleaving are performed on the transmit signal in blocks 16, 18, respectively. As is well known in the art, interleaving a block of data allows "bursty" errors to be distributed throughout the entire block. By so doing, the errors are more likely to be correctable by an error correction

device, such as a Viterbi decoder. The transmit signal is demultiplexed in block 20 to provide orthogonal I and Q bit stream signals. Power control information can be punctured into the bit stream signals in block 22. The resulting transmit signals are Walsh encoded in mixers 24 for each particular code channel. The resulting signals are filtered by finite impulse response filters 26. The Walsh codes are generated by Walsh generator 25, which is coupled to both mixers 24 and switch 28. The filtered transmit signals are applied to switch 28. Switch 28 couples the filtered transmit signal alternately to first and second adders 27. The adders combine other switch outputs for other code channels. The output of the adders 27 are coupled to upconverters 30, 32. Walsh generator 25 provides a signal to switch 28 which indicates when the Walsh boundaries occur, thus allowing the switch 28 to alternate change at the Walsh code boundaries. Figure 2 illustrates the permissible switching times, which occur at the Walsh code boundaries 301.

The switched signals from upconverters 30, 32 are transmitted by antennas 34, 36. The switch preferably switches at a rate that ensures several portions of each interleaver block are transmitted from each of the antennas 34, 36. Since a first group of code channels may be transmitted from the first antenna 34 at the same time as a second group of code channels is being transmitted from the second antenna 36, there is a need for two upconverters and two power amplifiers 30, 32.

In an alternate embodiment, impulse response filters 26 can be applied to the outputs of diversity switch 28 rather than to the inputs of diversity impulse response switch 28. This permits cleaner filtering of the transmit signals but requires twice as many impulse response filters 26. In either case, it is preferred that mobile units include pilot filters for receiving and processing pilot Walsh channel transmissions within switched antenna diversity system 10. The required PN spreading of the transmit signals can be performed within upconverters 30, 32.

When practicing the method of the present invention, diversity switch 28 applies the outputs of impulse response filters 26 alternately to Path A and Path B of diversity system 10 for alternate transmission from antennas 34, 36. The alternate transmissions from antennas 34, 36 have

different fade characteristics and can therefore be combined at the receiving unit to provide the required transmit diversity for the receiver unit. It will be understood that the present invention is described in a system for providing diversity signals by a base station to a mobile unit for illustrative purposes only. The present invention can be applied to any diversity transmission, including transmissions from a mobile unit having multiple mobile unit antennas to a base station or other receiver.

The switching and controller operations performed by diversity switch 28 can be obtained using any type of switching device suitable for alternately applying pilot and transmit signals to the multiple antenna paths of diversity system 10. For example, diversity switch 28 can be formed of convention digital logic switching circuits wherein digital switches corresponding to each antenna are alternately opened and closed. In an alternate embodiment of the invention, a pilot signal can be continuously applied to both antennas 34, 36, and the switching operations of diversity switch 28 can be performed upon the traffic signals only. This approach requires that the two pilot signals be orthogonal and can therefore increase interference between the transmit signals. Additionally, the switching operations can include another level of Walsh coding within switched antenna diversity system 10.

The speed of the switching of the transmit signals to the multiple paths of diversity system 10 is not critical. The switching can even be random. In general, if the switching speed is too slow it is difficult for the receiving unit to track the signals from the different antennas. Faster switching speeds make it easier for the receiving unit to track the signals from the different antennas. However, if the switching speed is too fast the frequency spectrum of the transmit signals is expanded causing interference with signals on adjacent carrier frequencies. In the preferred embodiment of the invention the switching period of antennas 34, 36 is equal to an integer multiple of the Walsh sequence period and occurs on Walsh code boundaries. This maintains the orthogonality of the channels. In switch antenna diversity system 10 having a chip rate of 3.6864 Mchips/s, the preferred antenna switching rate is every 512 chips.

Furthermore, it will be understood that the switching between antennas 34, 36 does not have to be ideal. For example, the trailing off of outputs from filters 26 may cause some overlap in the transmissions from antennas 34, 36 when transmission by one antenna terminates and
5 transmission from another initiates.

In an alternative embodiment of the present invention, switching is done on the entire forward link at once. That is, all of the code channels that make up the forward link are switched together. If the entire forward link is switched together, there need only be one upconverter and power
10 amplifier. The switch 28 is placed between a combiner, upconverter, and power amplifier 29 (shown as one block for simplicity) and the antenna, as shown in Figure 3.

Figure 4 illustrates the relationship between the signals that are sent from a base station over a first and second antenna, and the receipt of those
15 signals at a mobile unit. As shown in 401 and 403, the mobile unit receives a first signal on a first and third finger of a rake receiver within the mobile unit. Likewise, the mobile unit receives the second signal on a second and fourth finger of the rake receiver within the mobile unit. In practice, the base station antennas are located close enough to one another that the path
20 delays are almost the same from the two antennas. This would permit finger 1 and 3 (and 2 and 4) to be the same physical finger with the finger being switched quickly between paths 1 and 3 and 2 and 4.

The previous description of the preferred embodiments is provided to enable any person skilled in the art to make or use the present invention.
25 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 inventive faculty. Thus, the present invention is not intended to be limited to the methods and apparatuses shown herein but is to be accorded the widest scope consistent
30 with the claims set forth below.

What is claimed is:

CLAIMS

1. In a wireless telephone system including a transmitting station and
2 at least one receiving unit, the transmitting station having at least first and
second antennas for transmitting message information to the receiving unit,
4 a method for providing diversity transmissions from the transmitting
station to the receiving unit, comprising the steps of:

6 (a) transmitting message information from the first antenna of the
transmitting station to the receiving unit;

8 (b) terminating the transmitting of the message information from
the first antenna to the receiving unit and initiating the transmitting of the
10 message information from the second antenna of the transmitting station to
the receiving unit;

12 (c) after step (b), terminating the transmitting of the message
information from the second antenna to the receiving unit and initiating
14 the transmitting of the message information from the first antenna in the
transmitting station to the receiving unit; and

16 (d) repeatedly switching between the first and second antennas by
repeating steps (b) and (c).

2. The method of claim 1, wherein step (d) comprises periodically
2 repeating steps (b) - (c) at regular intervals.

3. The method of claim 2, wherein the message information is
2 transmitted from the first antenna in steps (a) and (c) using a first waveform,
the message information is transmitted from the second antenna in step (b)
4 using a second waveform, and the first waveform is orthogonal to the
second waveform.

4. The method of claim 3, wherein the message information is
2 transmitted from the first and second antennas using code division multiple
access (CDMA) modulation, the first waveform corresponds to a first Walsh

4 code, the second carrier waveform corresponds to a second Walsh code, and
the first Walsh code is orthogonal to the second Walsh code.

5. The method of claim 4, wherein a CDMA chip rate is associated
2 with the CDMA modulation, and the switching between the first and second
antennas occurs at a rate that is substantially smaller than the CDMA chip
4 rate.

6. The method of claim 5, wherein the switching between the first
2 and second antennas occurs after every 512 chips in the CDMA modulation.

7. The method of claim 5, wherein step (a) further comprises
2 transmitting a pilot signal from the transmitting station to the receiving
unit only on the first antenna, and step (b) comprises:

4 (b) terminating the transmitting of the message information and
the pilot signal from the first antenna to the receiving unit and initiating
6 the transmitting of the message information and the pilot signal from only
the second antenna in the transmitting station to the receiving unit;

8 and step (c) comprises:

(c) after step (b), terminating the transmitting of the message
10 information and the pilot signal from the second antenna to the receiving
unit and initiating the transmitting of the message information and the
12 pilot signal from only the first antenna in the transmitting station to the
receiving unit.

8. The method of claim 1, wherein step (a) further comprises
2 transmitting a first pilot signal from the transmitting station to the receiving
unit only on the first antenna and transmitting a second pilot signal from
4 the transmitting station to the receiving unit only on the second antenna,
wherein the first and second pilot signals are respectively transmitted from
6 the first and second antennas continuously during steps (a) - (d).

9. The method of claim 8, wherein the first pilot signal
2 transmitted from the first antenna is orthogonal to the second pilot signal
transmitted from the second antenna.

10. In a wireless telephone system including a transmitting station
2 and at least one receiving unit, the transmitting station having a plurality of
antennas for transmitting message information signals to the receiving unit,
4 an apparatus for providing diversity transmissions from the transmitting
station to the receiving unit, comprising:

6 (a) a first antenna associated with the transmitting station,
wherein the first antenna transmits message information from the
8 transmitting station to the receiving unit;

(b) a second antenna associated with the transmitting station,
10 wherein the second antenna transmits message information from the
transmitting station to the receiving unit;

12 (c) a controller that repeatedly switches from the first antenna to
the second antenna and then from the second antenna back to the first
14 antenna, the controller switching from the first antenna to the second
antenna by terminating the transmitting of the message information from
16 the first antenna to the receiving unit while initiating the transmitting of
the message information from the second antenna in the transmitting
18 station to the receiving unit, the controller switching from the second
antenna to the first antenna by terminating the transmitting of the message
20 information from the second antenna to the receiving unit and initiating
the transmitting of the message information from the first antenna in the
22 transmitting station to the receiving unit.

11. In a wireless telephone system including a transmitting station
2 and at least one receiving unit, the transmitting station having at least first
and second antennas for transmitting message information signals to the
4 receiving unit, an apparatus for providing diversity transmissions from the
transmitting station to the receiving unit, comprising:

(a) means for transmitting message information from only the first antenna in the transmitting station to the receiving unit;

(b) first means for terminating the transmitting of the message information from the first antenna to the receiving unit and initiating the transmitting of the message information from the second antenna in the transmitting station to the receiving unit;

(c) second means for terminating the transmitting of the message information from the second antenna to the receiving unit and initiating the transmitting of the message information from the first antenna in the transmitting station to the receiving unit; and

(d) switching means for alternatively actuating the first means for terminating and the second means for terminating.

12. A transmitter in a spread-spectrum communication system, comprising:

a first antenna;

a second antenna;

a spreading code generator adapted to provide a spreading code for transmission of a message from the first and second antennas; and

switching means responsive to the code generator to switch between the first and second antennas for transmission on a first communication link.

13. The transmitter as in claim 12, wherein the spreading code is a Walsh code.

14. The transmitter as in claim 12, wherein the switching means switches on a spreading code boundary.

15. The transmitter as in claim 12, wherein the switching means repeatedly switches between the first and second antennas for transmission on the first communication link.

16. The transmitter as in claim 12, wherein the transmission includes a plurality of code channels and wherein the spreading code generator is adapted to provide a plurality of spreading codes for transmission of a plurality of messages from the first and second antennas.
17. A transmitter in a spread-spectrum communication system, comprising:
 - a plurality of transmit antennas;
 - a spreading code generator adapted to provide a spreading code for transmission of a message from the plurality of transmit antennas; and
 - switching means responsive to the code generator to switch between the plurality of transmit antennas for transmission on a first communication link.
18. The transmitter as in claim 17, wherein the spreading code is a Walsh code.
19. The transmitter as in claim 17, wherein the switching means switches between the plurality of transmit antennas on occurrence of a spreading code boundary.
20. The transmitter as in claim 17, wherein the switching means switches between the plurality of transmit antennas redundantly with a switching period equal to an integer multiple of a sequence period of the spreading code.