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SPREAD SPECTRUM COMMUNICATION NETWORK

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WITH ADAPTIVE FREQUENCY AGILITY

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RELATED APPLICATIONS

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The present application incorporates the following
patent applications by reference:

10

CELLULAR PRIVATE BRANCH EXCHANGES, U.S. Ser. No.

11

08/435,709, filed on May 4, 1995, Attorney docket No.

12

WAVEP001;

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METHODS AND APPARATUSSES FOR AN INTELLIGENT SWITCH, U.S.

14

Ser. No. 08/435,838, filed on May 4, 1995, Attorney docket

15

No. WAVEP004;

16

SPREAD SPECTRUM COMMUNICATION NETWORK SIGNAL PROCESSOR,

17

U.S. Ser. No. 08/434,554, filed on May 4, 1995, Attorney

18

docket No. A-60910; and

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CELLULAR BASE STATION WITH INTELLIGENT CALL ROUTING,

20

U.S. Ser. No. 08/434,598, filed on May 4, 1995, Attorney

21

docket No. A-61115.

22

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FIELD

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The present invention relates to a spread spectrum
communication network with adaptive frequency agility. In
particular, the present invention is used in a cellular
communication network to improve the information channel
capacity by adapting the spread spectrum frequencies to
reduce interference and improve performance.

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BACKGROUND

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Spread spectrum communication typically includes two
type of techniques: direct sequence spread spectrum (DSSS),
where the information signal in-phase and quadrature-phase
are varied; and frequency hopping spread spectrum (FHSS),
where the information carrier frequency is varied. Moreover,
these techniques can include formats for what is known as
time division multiple access (TDMA) and frequency division

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1 multiple access (FDMA). These formats dedicate a specific
2 periodic time slot or frequency to each mobile station.
3 Advantages of DSSS, FHSS, TDMA and FDMA include reduced co-
4 channel interference and improved information channel
5 capacity over a given bandwidth. While these techniques can
6 be employed independently, they can also be combined.

7 One limitation of existing communication networks is
8 that the base station must have a multiplicity of dedicated
9 transmitters and receivers to adequately process all the
10 mobile station signals. Since each base station transmitter
11 and receiver can communicate only one frequency, a large
12 number of transmitters and receivers are required to serve
13 the communication network employing multiple frequencies.
14 For example, eight transmitters and eight receivers are
15 required to serve eight receive frequencies and eight
16 transmit frequencies.

17 Moreover, since existing communication networks use a
18 multiplicity of dedicated transmitters and receivers, a fault
19 can cause data to be lost, or even cause the network to
20 malfunction. When a transmitter or receiver is broken, the
21 network must operate in a reduced capacity, if it can operate
22 at all.

23 Another limitation of existing communication networks is
24 that the FHSS protocol sequence is predetermined. That is,
25 the frequency hops are periodic within the same frequency
26 set. This results in continual interference from other
27 operating electro-magnetic fields. The existing
28 communication protocols do not adapt to avoid interference.

29 Another limitation of existing communication networks is
30 that the processing is performed within a central signal
31 processor. A central signal processor employs software to
32 perform the procedures necessary to process the data. While
33 this configuration provides high flexibility, it is also slow
34 and requires high computational and memory overhead.

35 Another limitation of existing communication networks is
36 that in the communication protocol, the specific periodic
37 TDMA time slot is fixed. Each mobile station is entitled to
38 a single slot and may not receive an additional slot even if

1 other mobile stations are not fully utilizing their
2 respective information channel capacity.

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SUMMARY

5 The present invention relates to a spread spectrum
6 communication network with adaptive frequency agility. In
7 particular, the present invention is used in a cellular
8 communication network to improve the information channel
9 capacity by adapting the spread spectrum frequencies to
10 reduce interference and improve performance. Exemplary
11 embodiments are provided for use with the Global Systems for
12 Mobile Communication (GSM) protocol.

13 A base station communicates with a plurality of mobile
14 stations over a cellular network. In one embodiment, the
15 base station includes a receiver having a receiver
16 synthesizer input, where the receiver is configured to
17 receive inbound information from the mobile station on a
18 first predetermined frequency. The receiver further has two
19 programmable frequency sources that are configured to
20 alternately supply a receiver synthesizer input signal to the
21 receiver. The base station also includes a transmitter
22 having a transmitter synthesizer input, where the transmitter
23 is configured to transmit outbound information to the mobile
24 station on a second predetermined frequency. The transmitter
25 further has two programmable frequency sources that are
26 configured to alternately supply a transmitter synthesizer
27 input signal to the transmitter. A processor is connected to
28 the receiver and the transmitter and is configured to decode
29 the inbound information and to encode the outbound
30 information to communicate with the mobile station. This
31 two-way communication continues by programming and then
32 alternately selecting the receive synthesizers to receive on
33 the correct frequency, and by programming and then
34 alternately selecting the transmit synthesizers to transmit
35 on the correct frequency.

36 In another embodiment, the communication frequencies are
37 modified to reduce interference. The processor maintains
38 statistics on the communication error rates and modifies the

1 frequency hopping table (also known as a mobile allocation
2 table) to avoid error prone frequencies. This is an adaptive
3 modification based on the communication error rates with
4 respect to frequency. In a first aspect of the invention,
5 the base station gathers error rate statistics. In a second
6 aspect of this embodiment, both the base station and the
7 mobile station gather error rate statistics since they each
8 transmit and receive in different frequency bands. In a
9 third aspect of this embodiment, the base station has an
10 additional receiver that receives on the mobile station
11 receiver frequency band. The additional receiver scans the
12 available mobile station receive frequencies to identify
13 those frequencies that contain interference and those
14 frequencies that are clear. Then, the base station processor
15 modifies the frequency hopping table to avoid error prone
16 frequencies.

17 The advantages of the present invention include reduced
18 interference, improved communication bandwidth, fault
19 tolerance, and more efficient and cost-effective base
20 stations and mobile stations.

21

22 BRIEF DESCRIPTION OF THE DRAWINGS

23 Additional advantages of the invention will become
24 apparent upon reading the following detailed description and
25 upon reference to the drawings, in which:

26 Figure 1 depicts a cellular network showing several base
27 stations and several mobile stations;

28 Figures 2A-C illustrate the frequency bands allocated to
29 GSM communication, a typical frequency hopping table, and the
30 GSM frequency hopping algorithm;

31 Figure 3 illustrates a speech waveform sampled and
32 assembled into a digital GSM format;

33 Figure 4 illustrates a GSM frame and associated data;

34 Figure 5 depicts one embodiment of a base station
35 architecture according to the invention;

36 Figure 6 is a flow chart showing steps performed by the
37 base station of Figure 5 for controlling frequency;

38

1 Figure 7 depicts another embodiment of a base station
2 architecture according to the invention;

3 Figure 8 depicts one embodiment of a mobile station
4 according to the invention;

5 Figures 9A-B are flow charts showing steps performed by
6 the base station of Figure 5 and the mobile station of Figure
7 8 to gather and store statistics regarding communication
8 error rates;

9 Figure 10 depicts another embodiment of a base station
10 according to the invention, where the base station includes
11 an additional receiver to scan the mobile station receive
12 frequency band; and

13 Figure 11 is a flow chart showing steps performed by the
14 base station of Figure 10 to gather and store statistics
15 regarding communication error rates.

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DETAILED DESCRIPTION

18 The present invention relates to a spread spectrum
19 communication network with adaptive frequency agility. In
20 particular, the present invention is used in a cellular
21 communication network to improve the information channel
22 capacity by adapting the spread spectrum frequencies to
23 improve performance and reduce interference. Exemplary
24 embodiments are provided for use with the Global Systems for
25 Mobile Communication (GSM) communication protocol.

26 The exemplary embodiments are described herein with
27 reference to specific configurations and protocols. Those
28 skilled in the art will appreciate that various changes and
29 modifications can be made to the exemplary embodiments while
30 remaining within the scope of the present invention.

31 A first embodiment is described with reference to
32 Figures 1 through 6. Figure 1 is a relatively general
33 illustration of a cellular communication network. A number
34 of base stations (BS) 10 are positioned to serve a number of
35 geographically distinct cells, for example cell A and cell B.
36 Each base station 10 is responsible for serving all the
37 mobile stations (MS) 200 within its respective cell boundary.
38 To perform this task, each base station 10 downloads a

1 frequency hopping table (also known as a mobile allocation
2 table) to each mobile station 200 so that the communication
3 between base station 10 and mobile station 200 is on
4 predefined frequencies, as explained more fully below.

5 A base station controller (BSC) 12 is connected to every
6 base station 10, typically via land line 92, and controls the
7 communication between users, such as between mobile station
8 users or existing infrastructure telephone users. Moreover,
9 base station controller 12 controls the hand-off from one
10 base station 10 to another base station 10 as a mobile
11 station 200 moves among cells.

12 A protocol selected for the embodiments is the Global
13 Systems for Mobile Communication (GSM) protocol. The GSM
14 protocol is lengthy and complicated. Therefore, the salient
15 features are discussed with respect to the embodiments. For
16 additional information on the subject, the reader is referred
17 to the GSM specification. One important GSM protocol
18 requirement is frequency hopping spread spectrum (FHSS).
19 That is, sequentially communicating over more than one
20 frequency.

21 Figure 2A shows the allocated frequency spectrum for GSM
22 communication (from the mobile station standpoint). As can
23 be seen, the mobile station transmit frequency band (T_f) is
24 disjoint from the mobile station receive frequency band (R_f).
25 Each of these frequency bands occupies approximately 25MHz.
26 Within that 25MHz, there are 124 200KHz frequency steps on
27 which the communication frequencies are permitted to hop.
28 The specific hopping sequence is a function of the GSM
29 hopping algorithm defined by the GSM specification and a
30 given frequency hopping table that is downloaded from base
31 station 10 to mobile station 200. An example frequency
32 hopping table is presented in Figure 2B. Based on the GSM
33 hopping algorithm (Figure 2C), the mobile station receiver
34 and transmitter operate on specified 200KHz frequencies in
35 their respective frequency bands T_f , R_f . Of course, the base
36 station T_f and R_f correspond to the mobile station R_f and T_f
37 respectively.

38

1 Since GSM is a digital data communication network,
2 Figure 3 shows how a speech waveform is sampled and digitally
3 encoded. Figure 4 shows how the encoded data is formatted
4 into the GSM word. Note that the information from one mobile
5 station 200 is processed and placed into a specific time slot
6 reserved for that particular mobile station 200 within a TDMA
7 frame. Further, note that after the TDMA frame is collected,
8 a multiframe is constructed from 26 TDMA frames, including 24
9 TDMA speech frames and 2 control frames. Beyond the
10 multiframe are superframes and hyperframes. There are 51
11 multiframes in a superframe, and there are 2048 superframes
12 in a hyperframe. The hyperframe number is one variable used
13 by the GSM frequency hopping algorithm to define the
14 frequency hopping sequence.

15 Based on the GSM frequency hopping algorithm (Figure
16 2C), the TDMA frames are then frequency hopped over the
17 frequencies of the frequency hopping table. The mobile
18 station receivers are also periodically hopped onto a fixed
19 monitor frequency that is unique to each base station. The
20 frequency hopping serves to spread the communication signal
21 over the frequency bands T_f , R_f . An advantage of spread
22 spectrum is reduced interference effects from other electro-
23 magnetic sources and other base station/mobile station
24 communications. For the mobile station, three frequencies
25 are tuned onto in one 4.615ms TDMA time frame (transmit,
26 receive, monitor). Each mobile station transmitter and
27 receiver synthesizer has 1 or 2 time slots (4.615ms times 1/8
28 or 2/8, i.e., .58ms or 1.15ms) to change frequencies.
29 Frequency hopping once per frame is easily accomplished
30 because the synthesizers have plenty of time (1 or 2 time
31 slots) to settle before a new reception or transmission is
32 required. However, the base station receiver and transmitter
33 have only 30 μ s to change frequencies (the time duration of
34 the guard bits). This short time period is difficult to
35 accommodate, so the invention incorporates a plurality of
36 receiver synthesizers and transmitter synthesizers as now
37 explained.
38

1 Figure 5 depicts a base station 10 having a receiver 20,
2 a transmitter 40 and a processor 80. As shown, receiver 20
3 and transmitter 40 share common antenna 21 via diplexer 23.
4 This configuration is possible since the receive frequency
5 and transmit frequency are different (see Figure 2A).
6 Diplexer 23 is used to permit the receive frequency to pass
7 from antenna 21 to receiver 20, and to permit the transmit
8 frequency to pass from transmitter 40 to antenna 21.
9 Receiver 20 and transmitter 40 each employ two independent
10 synthesizers in order to facilitate fast frequency agility.
11 The detail of the embodiment and the operation is explained
12 with reference to the Figure 6 flow chart.

13 The reset step 102 is performed only at start-up, such
14 as when base station 10 initially comes on-line or when
15 recovering from a power failure. Step 104 is turns off
16 transmitter 40 to prevent invalid transmission before
17 initialization of the base station 10. Thereafter, step 106
18 waits for the processor 80 to perform its self-test and other
19 required procedures before base station 10 can become
20 operational in the cellular network. Step 108 calculates the
21 required first frequency and the subsequent second frequency
22 from the GSM hyperframe number and the frequency hopping
23 table. Once these first and second frequencies are
24 calculated, the first and second receiver synthesizers 32,
25 34, and transmitter synthesizers 52, 54 are programmed to
26 generate the required frequencies. At this point, the
27 switches 36, 56 are set to provide the mixers 24, 44 with the
28 frequencies from the first synthesizers 32, 52 respectively.

29 A loop sequence begins with step 110, where processor 80
30 waits for the transmitter interrupt from the CPU 82 to
31 indicate that the TDMA frame should be processed. If the
32 step 112 is being queried for the first time (i.e.,
33 transmitter 40 was turned off in step 104), step 114 is
34 performed to turn transmitter 40 on. Once transmitter 40 is
35 on, step 116 proceeds to transmit a TDMA frame and then to
36 toggle the transmitter synthesizer selector switch 56 to the
37 other transmitter synthesizer 54. Step 116 also calculates
38

1 the next transmitter frequency and programs the previously
2 active synthesizer 52 to generate that frequency.

3 When the receiver interrupt occurs in step 118, step
4 120 proceeds to receive a TDMA frame and then to toggle the
5 receiver synthesizer selector switch 36 to the other receiver
6 synthesizer 34. Step 120 also calculates the next receiver
7 frequency and programs the previously active synthesizer 32
8 to generate that frequency.

9 Steps 110 through 120 are then repeatedly performed to
10 transmit and receive the TDMA frames to and from the mobile
11 stations 200 on the proper frequencies. This configuration
12 of the dual synthesizer receiver 20 and dual synthesizer
13 transmitter 40 permits base station 10 to faithfully
14 accomplish all the frequency hops required for proper
15 communication.

16 It is important to note that base station 10 of Figure 5
17 employs processor 80 to orchestrate the synthesizers 32, 34,
18 52, 54 and the synthesizer switches 36, 56. Processor 80
19 includes a central processing unit (CPU) 82 for performing
20 many of the general procedures required to communicate over
21 the network with mobile station 200. Processor 80 also
22 performs procedures necessary to communicate with base
23 station controller 12. A digital signal processor (DSP) 84
24 is included in processor 80 to perform many of the
25 application specific and computationally intensive procedures
26 such as encoding and decoding the TDMA frame data. As shown,
27 the processor 80 also includes memory (RAM) 86 and bulk disk
28 memory 88. Moreover, user interface 90 is provided to
29 receive instructions from a user and to display requested
30 information. Ground line 92 is also provided to connect to
31 base station controller 12 and other base stations 10 as
32 required by the GSM specification.

33 In actual implementation, it is useful to employ a
34 plurality of receivers in order to perform both TDMA and
35 FDMA, as provided by the GSM specification. In a
36 conventional configuration, each receiver is tuned to a fixed
37 frequency and frequency-hopped information from the mobile
38 stations is received by various receivers depending on the

1 specified communication frequency. Then the conventional
2 processor must re-assemble inbound information from a
3 plurality of receivers to obtain data from one mobile
4 station. Moreover, the conventional processor must dis-
5 assemble outbound information and deliver it to a plurality
6 of transmitters to properly transmit information to a mobile
7 station.

8 Figure 7 depicts another embodiment of a base station 10
9 according to the invention. There are provided a plurality
10 of receivers 20A-J that are frequency agile (as shown in
11 Figure 5). Hence, receivers 20A-J can be programmed to
12 receive various frequencies over time and can receive
13 information from each mobile station 200 on a respective one
14 of receivers 20A-J. This feature permits both FDMA received
15 signals and TDMA received signals associated with one mobile
16 station 200 to be received by one of the receivers 20A-J.
17 Because processor 80 programs the receiver synthesizers,
18 processor 80 has a priori knowledge of which receiver 20A-J
19 is receiving communication signals from which mobile station
20 200. This information permits the processor to more
21 efficiently process the inbound data. For example, if the
22 signal from one mobile station 200 is always received in
23 receiver card one 20A, then the processor 80 can reduce its
24 control logic (hardware, software, or both) to avoid the
25 conventional step of re-assembling a mobile station's data
26 from a number of different receivers. Also, configuring a
27 plurality of frequency agile receivers 20A-J in parallel
28 permits processor 80 to reconfigure receivers 20A-J at any
29 time a fault is detected. If, for example, processor 80
30 detects a fault in receiver 20A (e.g., by self-test, null
31 data, or corrupted data), processor 80 re-programs another
32 receiver, such as receiver 20J, to operate on the parameters
33 that were previously assigned to receiver 20A. The feature
34 of agile receivers and enhanced processing resource
35 allocation reduces overhead, permits fault tolerance, and
36 increases throughput since it eliminates a processing step.

37 There are also provided a plurality of transmitters 40A-
38 K that are frequency agile (as in Figure 5). Hence,

1 transmitters 40A-K can be programmed to transmit various
2 frequencies over time and can transmit information to each
3 mobile station 200 on a respective one of transmitters 40A-K.
4 This feature permits both FDMA transmitted signals and TDMA
5 transmitted signals associated with one mobile station 200 to
6 be transmitted by one of the transmitters 40A-K. Because
7 processor 80 programs the transmitter synthesizers, processor
8 80 has a priori knowledge of which transmitter 40A-J is
9 transmitting communication signals to which mobile station
10 200. This information permits the processor to more
11 efficiently process the outbound data. For example, if the
12 signal to one mobile station 200 is always transmitted by
13 transmitter one 40A, then the processor 80 can reduce its
14 control logic (hardware, software, or both) to avoid the
15 conventional step of dis-assembling a mobile station's data
16 and delivering it to a number of different transmitters.
17 Also, configuring a plurality of frequency agile transmitters
18 40A-K in parallel permits processor 80 to reconfigure
19 transmitters 40A-K at any time a fault is detected. If, for
20 example, processor 80 detects a fault in transmitter 40A
21 (e.g., by self-test, null data received by the mobile
22 station, or corrupted data), processor 80 re-programs another
23 transmitter, such as transmitter 40K, to operate on the
24 parameters that were previously assigned to transmitter 40A.
25 The feature of agile transmitters and enhanced processing
26 resource allocation reduces overhead, permits fault
27 tolerance, and increases throughput since it eliminates a
28 processing step.

29 As shown, receivers 20A-J and transmitters 40A-K are
30 coupled to receive antenna 22 and transmit antenna 42
31 respectively. However, a common antenna 21 can be employed
32 as shown in Figure 5. Also as shown, transmitters 40A-K are
33 coupled to single transmit antenna 42. However, if
34 transmitters 40A-K are sensitive to back propagation of each
35 other's transmissions, a plurality of transmit antennas (42A-
36 K) can be employed with each transmitter having its own
37 transmit antenna. Moreover, corresponding receivers and
38 transmitters, e.g. 20A and 40A, 20B and 40B, 20C and 40C, can

1 be grouped and combined to have common antennas 21A, 21B and
2 21C respectively, as shown in Figure 5.

3 Additional base station embodiments are described in
4 CELLULAR BASE STATION WITH INTELLIGENT CALL ROUTING, U.S.
5 Ser. No. 08/434,598, filed on May 4, 1995, Attorney docket
6 No. A-61115, which is incorporated herein by reference.

7 A mobile station 200 is depicted in Figure 8. Mobile
8 station 200 is similar to base station 10, but requires less
9 hardware since the purpose is to serve only one user. A
10 receiver 220 is provided connected to a common antenna 222
11 via diplexer 223. Processor 280 reads the stored frequency
12 hopping table and calculates the proper receive frequency for
13 the inbound TDMA frame. Processor 280 then programs receiver
14 synthesizer 232 to generate that frequency. Receiver
15 synthesizer 232 provides the frequency to the receiver mixer
16 224, which down-mixes the received signal and provides an
17 information signal to processor 280. Processor 280 then
18 decodes the received TDMA frame. Processor 280 includes a
19 CPU 282, DSP 284, RAM 286 and user interface 290 (e.g. keypad
20 and LCD display), much like base station 10. A transmitter
21 240 is provided connected to the common antenna 222 via
22 diplexer 223. The CPU reads the frequency hopping table and
23 calculates the proper transmit frequency for the outbound
24 TDMA frame. Processor 280 then programs the transmitter
25 synthesizer 252 to generate that frequency. Processor 280
26 encodes the transmit TDMA frame data. Transmitter
27 synthesizer 252 then provides the transmit frequency to the
28 transmitter mixer 244, which up-mixes an information signal
29 containing the TDMA frame data and provides a radio frequency
30 signal to be transmitted via antenna 222.

31 In another embodiment, the frequency hopping table is
32 modified to reduce interference. This is done by continually
33 monitoring the error rates of the communication. Processor
34 80 maintains statistics on the communication error rates and
35 modifies the frequency hopping table to avoid error-prone
36 frequencies.

37 In a first aspect of this embodiment, shown in Figures
38 9A-B, base station 10 gathers error rate statistics. This

1 feature of gathering statistics of bit error rates (BER) is
2 included in the GSM protocol specification. Base station 10
3 operation is shown in Figure 9A flow chart 300. Receiver 20
4 receives the signal from mobile station 200 and decodes the
5 TDMA frame in step 302. Then the TDMA raw data is error-
6 corrected by the CPU 80 to obtain valid data. In step 304
7 the processor 80 builds a database storing the errors with
8 respect to frequency. Ordinarily the errors stored are bit
9 error rates (BER). If few errors are detected, step 308
10 continues the receiving steps for receiving the signal from
11 mobile station 200 without modification. However, if an
12 error-prone frequency is observed in step 306, step 310
13 calculates a different set of frequencies that may have less
14 error-prone tendencies and then re-programs base station 10
15 and mobile station 200 with a new frequency hopping table.
16 Step 310 may estimate which frequencies are less crowded, or
17 may look to the error rate database to avoid error-prone
18 frequencies.

19 In a second aspect of this embodiment, also described
20 with respect to Figures 9A-B, both base station 10 and mobile
21 station 200 gather statistics since they each transmit and
22 receive on different frequencies. This feature of gathering
23 error rate statistics of is included in the GSM communication
24 protocol specification. Base station 10 operation is shown
25 in Figure 9A flow chart 300. Receiver 20 receives the signal
26 from mobile station 200 and down-mixes the information signal
27 in step 302. Then the TDMA raw data is decoded by the
28 processor 80 and error corrected to obtain valid data. In
29 step 304 the processor 80 builds a database storing the
30 errors with respect to frequency. Ordinarily the errors
31 stored are bit error rates (BER). If few errors are
32 detected, step 308 continues the receiving steps for
33 receiving the signal from mobile station 200 without
34 modification. However, if an error-prone frequency is
35 observed in step 306, step 310 calculates a different set of
36 frequencies that may have less error-prone tendencies and
37 then re-programs base station 10 and mobile station 200 with
38 a new frequency hopping table. Step 310 may estimate which

1 frequencies are less crowded, or may look to the error rate
2 database to avoid error-prone frequencies.

3 Figure 9B shows mobile station 200 detecting and storing
4 error-rate statistics. The receiver 220 receives the signal
5 from the base station 10 and down-mixes the information
6 signal in step 322. Then the TDMA raw data is decoded by the
7 processor 280 and error corrected to obtain valid data. In
8 step 324 the processor 280 builds a database storing the
9 errors with respect to frequency. Ordinarily the errors
10 stored are bit error rates (BER). This information is
11 uploaded to base station 10 to make a determination of
12 whether the error-rate statistics warrant modifying the
13 mobile station transmit frequency hopping table. If an
14 error-prone frequency is observed in step 324, then Figure 9A
15 step 310 calculates a different set of frequencies that may
16 have less error-prone tendencies and then re-programs base
17 station 10 and mobile station 200 with a new frequency
18 hopping table. Step 310 may estimate which frequencies are
19 less crowded, or may look to the error rate database to avoid
20 error-prone frequencies.

21 In a third aspect of this embodiment depicted in Figure
22 10, base station 10 has an additional receiver 30 that
23 receives on the mobile station receiver frequency band. The
24 additional receiver 30 scans available frequencies to
25 identify frequencies that contain interference and
26 frequencies that are clear. Figure 11 shows a flow chart 450
27 where the receive frequency is received in step 452 and the
28 transmit frequency is received in step 454. In one
29 alternative, the receiver 30 is designed to scan the
30 frequencies for noise. The receiver 30 is never tuned to the
31 same frequency as the transmitter 40. This avoids saturation
32 of the receiver 30. In another alternative, the receiver 30
33 is located away from the transmitter 40, and the receiver 30
34 is tuned to the same frequency as the transmitter 40. In
35 either event, the purpose of the additional receiver 30 is to
36 employ a directly accessible receiver that provides either
37 noise level or error rate feedback to base station 10. Step
38 456 checks the noise threshold or error-rate of the signal

1 from receiver 30, and checks for interference on the transmit
2 frequency. If no significant data corruption or interference
3 is present, step 458 initiates step 460, which continues the
4 process from the beginning. However, if step 458 detects
5 high corruption or interference, then step 462 is executed to
6 modify the transmit frequency hopping table, the receive
7 frequency hopping table, or both.

8 Advantages of the present invention include reduced
9 interference, improved communication bandwidth, fault
10 tolerance, and more efficient and cost-effective base
11 stations and mobile stations.

12 As used herein, when a first element and a second
13 element are coupled, they are related to one another, but
14 need not have a direct path to one another. For example, an
15 antenna element may be coupled to a processing element via a
16 receiver. However, when a first element and second element
17 are connected, they are required to have a direct path to one
18 another.

19

20 ALTERNATIVE EMBODIMENTS

21 Having disclosed exemplary embodiments and the best
22 mode, modifications and variations may be made to the
23 disclosed embodiments while remaining within the scope of the
24 present invention as defined by the following claims.

1 What is claimed is:

2

3 1. A base station for communicating over a cellular network
4 with a mobile station, said base station comprising:

5 a receiver having a receiver synthesizer input, said
6 receiver configured to receive inbound information from the
7 mobile station on a predetermined frequency, said receiver
8 further having two receiver synthesizers that are configured
9 to alternately supply a receiver synthesizer signal to said
10 receiver synthesizer input;

11 a transmitter having a transmitter synthesizer input,
12 said transmitter configured to transmit outbound information
13 to the mobile station on a predetermined frequency, said
14 transmitter further having two transmitter synthesizers that
15 are configured to alternately supply a transmitter
16 synthesizer signal to said transmitter synthesizer input;

17 a processor coupled to said receiver and said
18 transmitter and configured to decode said inbound information
19 and to encode said outbound information to communicate with
20 the mobile station.

21

22 2. The base station of claim 1, wherein:

23 said two receiver synthesizers each include a voltage
24 controlled oscillator combined with a phase-locked feedback
25 loop to maintain a respective first receiver synthesizer
26 frequency and second receiver synthesizer frequency, and
27 wherein said two receiver synthesizers are coupled to said
28 processor;

29 said receiver further includes a switch coupled to each
30 of said receiver synthesizers, and selectable between a first
31 position to deliver said first receiver synthesizer frequency
32 to said receiver synthesizer input and a second position to
33 deliver said second receiver synthesizer frequency to said
34 receiver synthesizer input;

35 said two transmitter synthesizers each include a voltage
36 controlled oscillator combined with a phase-locked feedback
37 loop to maintain a respective first transmitter synthesizer
38 frequency and second transmitter synthesizer frequency, and



1 wherein said two receiver synthesizers are coupled to said
2 processor; and

3 said transmitter further includes a switch coupled to
4 each of said transmitter synthesizers, and selectable between
5 a first position to deliver said first transmitter
6 synthesizer frequency to said transmitter synthesizer input
7 and a second position to deliver said second transmitter
8 synthesizer frequency to said transmitter synthesizer input.

9

10 3. The base station of claim 1 for further communicating
11 with a second mobile station, said base station further
12 comprising:

13 a second receiver having a second receiver synthesizer
14 input, said second receiver configured to receive second
15 inbound information from the second mobile station on a
16 predetermined frequency, said second receiver further having
17 two receiver synthesizers that are configured to alternately
18 supply a receiver synthesizer signal to said second receiver
19 synthesizer input; and

20 wherein said processor is further coupled to said second
21 receiver and configured to decode said second inbound
22 information to communicate with the second mobile station.

23

24 4. The base station of claim 3, further comprising:

25 a second transmitter having a second transmitter
26 synthesizer input, said second transmitter configured to
27 transmit second outbound information to the second mobile
28 station on a predetermined frequency, said second transmitter
29 further having two transmitter synthesizers that are
30 configured to alternately supply a second transmitter
31 synthesizer signal to said second transmitter synthesizer
32 input; and

33 wherein said processor is coupled to said second
34 transmitter and configured to encode said second outbound
35 information to communicate with the second mobile station.

36

37

38



1 5. The base station of claim 1 for further communicating
2 with a second mobile station, said base station further
3 comprising:

4 a second transmitter having a second transmitter
5 synthesizer input, said transmitter configured to transmit
6 second outbound information to the mobile station on a
7 predetermined frequency, said second transmitter further
8 having two transmitter synthesizers that are configured to
9 alternately supply a transmitter synthesizer signal to said
10 second transmitter synthesizer input;

11 wherein said processor is coupled to said second
12 transmitter and configured to encode said second outbound
13 information to communicate with the second mobile station.
14

15 6. The base station of claim 3, wherein:

16 said processor is configured to reprogram said second
17 receiver when said first transmitter is broken.
18

19 7. The base station of claim 5, wherein:

20 said processor is configured to reprogram said second
21 transmitter when said first transmitter is broken.
22

23 8. A method of communicating over a cellular network
24 between a mobile station and a base station having a
25 processor, and a transmitter containing a first transmitter
26 frequency source and a second transmitter frequency source,
27 said method comprising the steps of:

28 (a) receiving, via the receiver, an initialization
29 signal from the mobile station;

30 (b) computing a first transmit frequency from
31 predetermined timing information;

32 (c) tuning said first transmitter frequency source to
33 generate said first transmit frequency;

34 (d) supplying the first transmit frequency to the
35 transmitter;

36 (e) modulating the first transmit frequency with a first
37 transmit signal representing information, said modulating
38 step producing a second transmit signal;



1 (f) transmitting the second transmit signal, via the
2 transmitter, to the mobile station;
3 (g) computing a second transmit frequency from
4 predetermined timing information plus one;
5 (h) tuning said second transmitter frequency source to
6 generate said second transmit frequency;
7 (i) supplying the second transmit frequency to the
8 transmitter;
9 (j) modulating the second transmit frequency with a
10 third transmit signal representing information, said
11 modulating step producing a fourth transmit signal;
12 (k) transmitting the fourth transmit signal, via the
13 transmitter, to the mobile station;
14 (l) repeating steps (b) through (k) with newly computed
15 frequencies from the predetermined timing information.
16
17 9. The method of claim 8, wherein said predetermined timing
18 information is the hyperframe number.
19
20 10. The method of claim 8, wherein said base station further
21 has a receiver containing a first receiver frequency source
22 and a second receiver frequency source, said method further
23 comprising the steps of:
24 (m) computing a first receive frequency from
25 predetermined timing information;
26 (n) tuning said first receiver frequency source to
27 generate said first receive frequency;
28 (o) supplying the first receive frequency to the
29 receiver;
30 (p) receiving a first receive signal, via the receiver,
31 from the mobile station;
32 (q) demodulating the first receive signal with the first
33 receive frequency, said demodulating step producing a second
34 receive signal representing information;
35 (r) computing a second receive frequency from
36 predetermined timing information plus one;
37 (s) tuning said second receiver frequency source to
38 generate said second receive frequency;



- 1 (t) supplying the second receive frequency to the
2 receiver;
- 3 (u) receiving a third receive signal, via the receiver,
4 from the mobile station;
- 5 (v) demodulating the third receive signal with the
6 second receive frequency, said demodulating step producing a
7 fourth receive signal representing information;
- 8 (w) repeating steps (m) through (v) with a newly
9 computed first receive frequency and second receive frequency
10 from said predetermined timing information.
- 11
- 12 11. The method of claim 10, wherein said predetermined
13 timing information is the hyperframe number.
- 14
- 15 12. A method of communicating over a cellular network
16 between a mobile station and a base station having a
17 processor, and a receiver containing a first receiver
18 frequency source and a second receiver frequency source, said
19 method comprising the steps of:
- 20 (a) computing a first receive frequency from
21 predetermined timing information;
- 22 (b) tuning said first receiver frequency source to
23 generate said first receive frequency;
- 24 (c) supplying the first receive frequency to the
25 receiver;
- 26 (d) receiving a first receive signal, via the receiver,
27 from the mobile station;
- 28 (e) demodulating the first receive signal with the first
29 receive frequency, said demodulating step producing a second
30 receive signal representing information;
- 31 (f) computing a second receive frequency from
32 predetermined timing information plus one;
- 33 (g) tuning said second receiver frequency source to
34 generate said second receive frequency;
- 35 (h) supplying the second receive frequency to the
36 receiver;
- 37 (i) receiving a third receive signal, via the receiver,
38 from the mobile station;



1 (j) demodulating the third receive signal with the
2 second receive frequency, said demodulating step producing a
3 fourth receive signal representing information;
4 (k) repeating steps (a) through (j) with a newly
5 computed first receive frequency and second receive frequency
6 from said predetermined timing information.

7
8 13. The method of claim 12, wherein said predetermined
9 timing information is the hyperframe number.

10

11 14. A method of communicating over a cellular network
12 between two mobile stations and a base station having a
13 processor and two frequency agile transmitters, said method
14 comprising the steps of:

15 tuning the first transmitter to transmit outbound
16 information to the first mobile station;

17 tuning the second transmitter to transmit outbound
18 information to the second mobile station; and

19 when said second transmitter breaks, tuning the first
20 transmitter to transmit outbound information to the second
21 mobile station.

22

23 15. The method of claim 14, wherein said base station further
24 has two frequency agile receivers, said method further
25 comprising the steps of:

26 tuning the first receiver to receive inbound information
27 from the first mobile station;

28 tuning the second receiver to receive inbound
29 information from the second mobile station; and

30 when said second receiver breaks, tuning the first
31 receiver to receive inbound information from the second
32 mobile station.

33

34 16. A method of communicating over a cellular network
35 between two mobile stations and a base station having a
36 processor and two frequency agile receivers, said method
37 comprising the steps of:

38



1 tuning the first receiver to receive inbound information
2 from the first mobile station;
3 tuning the second receiver to receive inbound
4 information from the second mobile station; and
5 when said second receiver breaks, tuning the first
6 receiver to receive inbound information from the second
7 mobile station.

8

9 17. A base station for communicating over a cellular network
10 with a mobile station, comprising:

11 a receiver configured to receive inbound information
12 from the mobile station on a first predetermined frequency;

13 a transmitter configured to transmit outbound
14 information to the mobile station on a second predetermined
15 frequency; and

16 a processor coupled to said receiver and said
17 transmitter and configured to decode said inbound information
18 and to encode said outbound information, said processor
19 further configured to store statistics regarding the
20 communication error rate over said first predetermined
21 frequency, and when said statistics indicate a high error
22 rate, to modify said first predetermined frequency.

23

24 18. The base station of claim 17, wherein:

25 said processor is further configured to store a
26 frequency table representing the available frequencies, and
27 to modify said frequency table to modify said first
28 predetermined frequency.

29

30 19. The base station of claim 17, wherein:

31 said processor is further configured to store statistics
32 regarding the communication error rate over said second
33 predetermined frequency, and when said statistics indicate a
34 high error rate, to modify said second predetermined
35 frequency.

36

37

38



1 20. The base station of claim 19, wherein:

2 said processor is further configured to store a
3 frequency table representing the available frequencies, and
4 to modify said frequency table to modify said second
5 predetermined frequency.
6

7 21. The base station of claim 17, wherein:

8 said receiver is further configured to scan available
9 frequencies; and

10 said processor is further configured to modify said
11 first predetermined frequency and said second predetermined
12 frequency based on a scan of said available frequencies.
13

14 22. The base station of claim 17, further comprising:

15 a second receiver coupled to said processor, said second
16 receiver configured to receive said second predetermined
17 frequency and to provide information regarding said second
18 predetermined frequency to said processor.
19

20 23. The base station of claim 22, wherein:

21 said second receiver is configured to scan the available
22 second communication frequency band and to provide said
23 processor with information regarding the presence of noise on
24 any available second predetermined frequency.
25

26 24. A method of communicating over a cellular network

27 between a mobile station and a base station having a
28 receiver, and a processor, said method comprising the steps
29 of:

30 receiving inbound information from the mobile station on
31 a predetermined frequency;

32 decoding said inbound information;

33 error-correcting said inbound information;

34 storing error statistics regarding the errors detected
35 in said error-correcting step; and

36 when the error statistics exceed a predetermined
37 threshold, modifying said predetermined frequency.
38



- 1 25. The method of claim 24, said base station further
2 comprising a transmitter, said method comprising the steps
3 of:
4 encoding outbound information;
5 transmitting said outbound information to the mobile
6 station on a second predetermined frequency;
7 receiving second error statistics regarding errors
8 detected in said transmitting step;
9 storing said second error statistics; and
10 when the second error statistics exceed a predetermined
11 threshold, modifying said second predetermined frequency.
12
- 13 26. A method of communicating over a cellular network
14 between a mobile station and a base station having a
15 transmitter, and a processor, said method comprising the
16 steps of:
17 encoding outbound information;
18 transmitting said outbound information to the mobile
19 station on a second predetermined frequency;
20 receiving second error statistics regarding errors
21 detected in said transmitting step;
22 storing said second error statistics; and
23 when the second error statistics exceed a predetermined
24 threshold, modifying said second predetermined frequency.
25
- 26 27. A method of communicating over a cellular network
27 between a mobile station and a base station having a
28 receiver, transmitter and processor, said method comprising
29 the steps of:
30 receiving, at the base station, an off-hook signal from
31 the mobile station;
32 scanning a plurality of available frequency in a
33 predetermined frequency band;
34 determining, from said scanning step, a plurality of
35 preferred frequencies;
36 determining, from the plurality of preferred
37 frequencies, a preferred hopping sequence of said preferred
38 frequencies;



- 1 transmitting to the mobile station the preferred hopping
- 2 sequence; and
- 3 communicating between the mobile station and the base
- 4 station over the preferred hopping sequence of frequencies.

