

HIGH-DATA-RATE SUPPLEMENTAL CHANNEL FOR CDMA TELECOMMUNICATIONS SYSTEM

BACKGROUND OF THE INVENTION

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I. Field of the Invention

The present invention relates to wireless telecommunications. More particularly, the present invention relates to a novel and improved method
10 for implementing a high-transmission-rate over-the-air interface.

II. Description of the Related Art

The IS-95 standard from the Telecommunications Industry
15 Association (TIA), and its derivatives such as IS-95A and ANSI J-STD-008 (referred to herein collectively as IS-95), define an over-the-air interface suitable for implementing a bandwidth-efficient digital cellular telephone system. To this end, IS-95 provides a method for establishing multiple radio
20 frequency (RF) traffic channels, each having a data transmission rate of up to 14.4 kilobits per second. The traffic channels can be used for conducting voice telephony or for conducting digital data communications including small file transfer, electronic mail, and facsimile.

While 14.4 kilobits per second is adequate for these types of lower data
rate applications, the increasing popularity of more data intensive
25 applications such as worldwide web and video conferencing has created a demand for much higher transmission rates. To satisfy this new demand, the present invention is directed towards providing an over-the-air interface capable of higher transmission rates.

FIG. 1 illustrates a highly simplified digital cellular telephone system
30 configured in a manner consistent with the use of IS-95. During operation, telephone calls and other communications are conducted by exchanging data between subscriber units 10 and base stations 12 using RF signals. The communications are further conducted from base stations 12 through base
station controllers (BSC) 14 and mobile switching center (MSC) 16 to either
35 public switch telephone network (PSTN) 18, or to another subscriber unit 10. BSC's 14 and MSC 16 typically provide mobility control, call processing, and call routing functionality.

In an IS-95 compliant system, the RF signals exchanged between
subscriber units 10 and base stations 12 are processed in accordance with code
40 division multiple access (CDMA) signal processing techniques. The use of

CDMA signal processing techniques allows adjacent base stations 12 to use the same RF bandwidth which, when combined with the use of transmit power control, makes IS-95 more bandwidth efficient than other cellular telephone systems.

5 CDMA processing is considered a "spread spectrum" technology because the CDMA signal is spread over a wider amount of RF bandwidth than is generally used for non-spread spectrum systems. The spreading bandwidth for an IS-95 system is 1.2288 MHz. A CDMA-based digital wireless telecommunications system configured substantially in accordance
10 with the use of IS-95 is described in US Patent 5,103,450 entitled "SYSTEM AND METHOD FOR GENERATING SIGNAL WAVEFORMS IN A CDMA CELLULAR TELEPHONE SYSTEM," assigned to the assignee of the present invention and incorporated herein by reference.

It is anticipated that the demand for higher transmission rates will be
15 greater for the forward link than for the reverse link because a typical user is expected to receive more data than he or she generates. The forward link signal is the RF signal transmitted from a base station 12 to one or more subscriber units 10. The reverse link signal is the RF signal transmitted from subscriber unit 10 to a base station 12.

20 FIG. 2 illustrates the signal processing associated with an IS-95 forward link traffic channel, which is a portion of the IS-95 forward link signal. The forward link traffic channel is used for the transmission of user data from a base station 12 to a particular subscriber unit 10. During normal operation, the base station 12 generates multiple forward link traffic channels, each of
25 which is used for communication with a particular subscriber unit 10. Additionally, the base station 12 generates various control channels including a pilot channel, a sync channel, and a paging channel. The forward link signal is the sum of the traffic channels and control channels.

As shown in FIG. 2, user data is input at node 30 and processed in
30 millisecond (ms) blocks called frames. The amount of data in each frame may be one of four values with each lower value being approximately half of the next higher value. Also, two possible sets of frame sizes can be utilized, which are referred to as rate set one and rate set two.

For rate set two the amount of data contained in the largest, or "full-
35 rate," frame corresponds to a transmission rate of 13.35 kilobits per second. For rate set one the amount of data contained in the full rate frame corresponds to a transmission rate of 8.6 kilobits per second. The smaller sized frames are referred to as half-rate, quarter-rate, and eighth-rate frames.

The various frame rates are used to adjust for the changes in voice activity experienced during a normal conversation.

CRC generator 36 adds CRC data with the amount of CRC data generated dependent on the frame size and rate set. Tail byte generator 40
5 adds eight tail bits of known logic state to each frame to assist during the decoding process. For full-rate frames, the number of tail bits and CRC bits brings the transmission rate up to 9.6 and 14.4 kilobits per second for rate set one and rate set two.

The data from tail byte generator 40 is convolutionally encoded by
10 encoder 42 to generate code symbols 44. Rate 1/2, constraint length (K) 9, encoding is performed.

Puncture 48 removes 2 of every 6 code symbols for rate set two frames, which effectively reduces the encoding performed to rate 2/3. Thus, at the output of puncture 48 code symbols are generated at 19.2 kilosymbols per
15 second (ksps) for both rate set one and rate set two full-rate frames.

Block interleaver 50 performs block interleaving on each frame, and the interleaved code symbols are modulated with a Walsh channel code from Walsh code generator 54 generating sixty-four Walsh symbols for each code symbol. A particular Walsh channel code W_i is selected from a set of
20 sixty-four Walsh channel codes and typically used for the duration of an interface between a particular subscriber unit 10 and a base station 12.

The Walsh symbols are then duplicated, and one copy is modulated with an in-phase PN spreading code (PN_I) from spreading code generator 52, and the other copy is modulated with a quadrature-phase PN spreading code
25 (PN_Q) from spreading code generator 53. The in-phase data is then low-pass filtered by LPF 58 and modulated with an in-phase sinusoidal carrier signal. Similarly, the quadrature-phase data is low-pass filtered by LPF 60 and modulated with a quadrature-phase sinusoidal carrier. The two modulated carrier signals are then summed to form signal $s(t)$ and transmitted as the
30 forward link signal.

SUMMARY OF THE INVENTION

35 The present invention is a novel and improved method for implementing a high-transmission-rate over-the-air interface. A transmit system provides an in-phase channel set and a quadrature-phase channel set. The in-phase channel set is used to provide a complete set of orthogonal medium rate control and traffic channels. The quadrature-phase channel set
40 is used to provide a high-rate supplemental channel and an extended set of

medium rate channels that are orthogonal to each other and the original medium rate channels. The high-rate supplemental channel is generated over a set of medium rate channels using a short channel code. The medium rate channels are generated using a set of long channel codes.

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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 is a block diagram of a cellular telephone system;

FIG. 2 is a block diagram of the forward link signal processing associated with the IS-95 standard;

FIG. 3 is a block diagram of a transmit system configured in accordance with one embodiment of the invention;

FIG. 4 is a list of the set of 64-symbol Walsh codes and associated indexes used in a preferred embodiment of the invention.

FIG. 5 is a block diagram of the channel coding performed in accordance with one embodiment of the invention;

FIG. 6 is a block diagram of a receive system configured in accordance with one embodiment of the invention; and

FIG. 7 is a block diagram of a decoding system configured in accordance with one embodiment of the invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

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FIG. 3 is a block diagram of a transmit system configured in a manner consistent with use of the invention. Typically, the transmit system will be used to generate the forward link signal in a cellular telephone system and therefore would be incorporated into a base station 12. In the exemplary configuration shown, the transmit system generates a forward link signal that includes a complete set of IS-95, or medium rate, channels as well as a high-speed supplemental channel. Additionally, in the embodiment described, an extended set of IS-95 channels is provided. Alternative embodiments of the invention could provide more than one high-speed supplemental channel, or not provide the use of an additional set of IS-95 channels, or both. Also, while providing IS-95 channels is preferred, other

embodiments of the invention may incorporate other channel types and processing protocols.

In the exemplary embodiment provided, the transmit system provides an in-phase channel set 90 and a quadrature-phase channel set 92.

5 The in-phase channel set 90 is used to provide the complete set of orthogonal IS-95 control and traffic channels. Orthogonal channel to not interfere with one another when transmitted via the same path. The quadrature-phase channel set 92 is used to provide a high-rate supplemental channel and an extended set of IS-95 channels that are orthogonal to each
10 other and the original IS-95 channels. In the preferred embodiment of the invention, all the signals and data shown in FIG. 3 are formed by positive and negative integer values represented by binary digital data or voltages, which correspond to a logic low and a logic high, respectively.

For the in-phase channel set 90, IS-95 control channel system 100
15 performs various functions associated with one of the standard IS-95 control channels including encoding and interleaving, the processing of which is described in IS-95 incorporated herein by reference. In this case, since the Walsh₁ channel code is used, the processing will be in accordance with the use of a paging channel. The resulting code symbols from IS-95 control
20 channel system 100 are modulated with a Walsh code from Walsh₁ generator 102 by multiplier 104. The Walsh generators 102 are used to generate the orthogonal in-phase channels.

Walsh generator 102 repeatedly generates a Walsh code of index 1 (Walsh₁) from a set of Walsh codes of indexes 0 to 63 (Walsh₀₋₆₃). FIG. 4 is a
25 list of the set of 64-symbol Walsh codes and associated indexes used in a preferred embodiment of the invention. A Walsh chip corresponds to a Walsh symbol and a Walsh chip value of 0 corresponds to a positive (+) integer while a Walsh chip value of 1 corresponds to a negative (-) integer. Under IS-95 Walsh₁ code corresponds to the paging channel. The Walsh
30 symbols generated by modulation with the Walsh₁ code are gain adjusted by channel gain 108(2).

The pilot channel is generated by gain adjusting a positive 1 value using channel gain 108(1). No encoding is performed for the pilot channel in accordance with IS-95, as the Walsh₀ code used for the pilot channel is all
35 plus 1 values, and therefore equivalent to no modulation at all.

Additional control channels are generated in similar fashion using additional IS-95 control channel systems, additional Walsh generators, and additional channel gains (all not shown). Such control channels include a synchronization channel, which is modulated with the Walsh₃₂ code. The

processing associated with each type of IS-95 control channel is described in IS-95.

The processing associated with one of the IS-95 traffic channels in the in-phase channel set is illustrated with IS-95 traffic channel system 110, which performs various functions associated with an IS-95 traffic channel including convolutional encoding and interleaving as described above to generate a sequence of symbols at 19.2 kilosymbols per second. The code symbols from IS-95 traffic channel system 110 are modulated with the 64-symbol Walsh₆₃ code from Walsh₆₃ generator 112 by multiplier 114 to generate a sequence of symbols at 1.2288 Megasymbols per second. The Walsh symbols from multiplier 114 are gain adjusted by gain adjust 108(64).

The outputs of all gain adjusts including gain adjusts 108(1) - (64) are summed by summer 120 generating in-phase data D_I . Each gain adjust 108 increases or decreases the gain of the particular channel with which it is associated. The gain adjust can be performed in response to a variety of factors including power control commands from the subscriber unit 10 processing the associated channel, or to differences in the type of data being transmitted over the channel. By keeping the transmit power of each channel at the minimum necessary for proper communication, interference is reduced and the total transmit capacity increased. In one embodiment of the invention, gain adjusts 108 are configured by a control system (not shown) which could take the form of a microprocessor.

Within quadrature-phase channel set 92, an extended set of $64 - 2^N$ IS-95 traffic channels are provided using IS-95 channel systems 124. N is a integer value based on the number of Walsh channels allocated for the supplemental channel and is described in greater detail below. Each code symbols from the IS-95 channel systems 124(2) - $(64 - 2^N)$ is modulated with a Walsh code from Walsh generators 126 by multipliers 128, except for IS-95 traffic channel system 124(1), which is placed on Walsh₀ channel, and therefore does not require modulation.

To provide the high-rate supplemental channel, supplemental channel system 132 generates code symbols at a rate R_S , which is 2^N times that of a full-rate IS-95 traffic channel. Each code symbol is modulated with a supplemental Walsh code (Walsh_S) from supplemental Walsh code generator 134 using multiplier 140. The output of multiplier 140 is gain adjusted by gain adjust 130. The outputs of the set of gain adjusts 130 are summed by summer 150 yielding quadrature-phase data D_Q . It should be understood that the extended set of IS-95 traffic channel could be completely or partially replaced with one or more additional supplemental channels.

The processing performed by supplemental channel system 132 is described in greater detail below. The Walsh_s code generated by supplemental Walsh code generator 134 depends the number of Walsh codes allocated for the high-rate supplemental channel in quadrature-phase channel set 92. In the preferred embodiment of the invention, the number of Walsh channels allocated for the high-rate supplemental channel can be any value 2^N where $N = \{2, 3, 4, 5, 6\}$. The Walsh_s codes are $64/2^N$ symbols long, rather than the 64 symbols used with the IS-95 Walsh codes. In order for the high-rate supplemental channel to be orthogonal to the other quadrature-phase channels with 64-symbol Walsh codes, 2^N of the possible 64 quadrature-phase channels with 64-symbol Walsh codes cannot be used for the other quadrature-phase channels. Table I provides a list of the possible Walsh_s codes for each value of N and the corresponding sets of allocated 64-symbol Walsh codes.

N	Walsh _i	Allocated 64-Symbol Walsh Codes
2	+,+,+,+,+,+,+,+,+,+,+,+,+,+,+	0, 16, 32, 48
	+,-,+,-,+,-,+,-,+,-,+,-,+,-,+,-	1, 17, 33, 49
	+,+,-,-,+,-,+,-,+,-,+,-,+,-,+,-	2, 18, 34, 50
	+,-,-,+,-,+,-,+,-,+,-,+,-,+,-,+,-	3, 19, 35, 51
	+,+,+,-,-,-,-,+,-,+,-,-,-,-,-	4, 20, 36, 52
	+,-,+,-,+,-,+,-,+,-,+,-,+,-,+,-	5, 21, 37, 53
	+,+,-,-,-,-,+,-,+,-,-,-,-,-	6, 22, 38, 54
	+,-,-,+,-,+,-,+,-,+,-,+,-,+,-,+,-	7, 23, 39, 55
	+,+,+,+,+,+,+,-,-,-,-,-,-,-,-	8, 24, 40, 56
	+,-,+,-,+,-,+,-,+,-,+,-,+,-,+,-	9, 25, 41, 57
	+,+,-,-,+,-,+,-,+,-,+,-,+,-,+,-	10, 26, 42, 58
	+,-,-,+,-,+,-,+,-,+,-,+,-,+,-,+,-	11, 27, 43, 59
	+,+,+,-,-,-,-,+,-,+,-,-,-,-,-	12, 28, 44, 60
	+,-,+,-,+,-,+,-,+,-,+,-,+,-,+,-	13, 29, 45, 61
	+,+,-,-,-,-,+,-,+,-,-,-,-,-	14, 30, 46, 62
	+,-,-,+,-,+,-,+,-,+,-,+,-,+,-,+,-	15, 31, 47, 63
3	+,+,+,+,+,+,+	0, 8, 16, 24, 32, 40, 48, 56
	+,-,+,-,+,-,+,-	1, 9, 17, 25, 33, 41, 49, 57
	+,+,-,-,+,-,+,-	2, 10, 18, 26, 34, 42, 50, 58
	+,-,-,+,-,+,-,+,-	3, 11, 19, 27, 35, 43, 51, 59
	+,+,+,-,-,-,-	4, 12, 20, 28, 36, 44, 52, 60
	+,-,+,-,+,-,+,-	5, 13, 21, 29, 37, 45, 53, 61
	+,+,-,-,-,-,+,-	6, 14, 22, 30, 38, 46, 54, 62
	+,-,-,+,-,+,-,+,-	7, 15, 23, 31, 39, 47, 55, 63
4	+,+,+,+	0, 4, 8, ..., 60
	+,-,+,-	1, 5, 9, ..., 61
	+,+,-,-	2, 6, 10, ..., 62
	+,-,-,+	3, 7, 11, ..., 63
5	+,+	0, 2, 4, ..., 62
	+,-	1, 3, 5, ..., 63
6	+	0, 1, 2, ..., 63

Table I.

The + and - indicate a positive or negative integer value, where the preferred integer is 1. As is apparent, the number of Walsh symbols in each Walsh_s code varies as N varies, and in all instances is less than the number

of symbols in the IS-95 Walsh channel codes. Thus, the supplemental channel is formed using a short Walsh channel code and the IS-95 channels are formed using longer Walsh channel codes. Regardless of the length of the Walsh_s code, in the described embodiment of the invention the symbols
5 are applied at a rate of 1.2288 Megachips per second (Mcps). Thus, shorter length Walsh_s codes are repeated more often.

Data channels D_I and D_Q are complex multiplied, as the first real and imaginary terms respectively, with spreading codes PN_I and PN_Q , as the second real and imaginary terms respectively, yielding in-phase (or real)
10 term X_I and quadrature-phase (or imaginary) term X_Q . Spreading codes PN_I and PN_Q are generated by spreading code generators 152 and 154. Spreading codes PN_I and PN_Q are applied at 1.2288 Mcps. Equation (1) illustrates the complex multiplication performed.

$$15 \quad (X_I + jX_Q) = (D_I + jD_Q)(PN_I + jPN_Q) \quad (1)$$

In-phase term X_I is then low-pass filtered to a 1.2288 MHz bandwidth (not shown) and upconverted by multiplication with in-phase carrier $\cos(\omega_c t)$. Similarly, quadrature-phase term X_Q is low-pass filtered to a 1.2288
20 MHz bandwidth (not shown) and upconverted by multiplication with quadrature-phase carrier $\sin(\omega_c t)$. The upconverted X_I and X_Q terms are summed yielding forward link signal $s(t)$.

The complex multiplication allows quadrature-phase channel set 92 to remain orthogonal to the in-phase channel set 90 and therefore to be
25 provided without adding additional interference to the other channels transmitted over the same path with perfect receiver phase recovery. Thus, a complete set of sixty-four Walsh_i channels is added in an orthogonal manner to the original IS-95 channel set, and this channel set can be used for the supplemental channel. Additionally, by implementing the
30 supplemental channel in the orthogonal quadrature-phase channel set 92, a subscriber unit 10 configured to process the normal IS-95 forward link signal will still be able to process the IS-95 channels within in-phase channel set 90 thus providing the high-transmission-rate channel while maintaining backwards compatibility with previously existing systems.

35 While the embodiment of the invention shown in FIG. 3 uses a single set of in-phase and quadrature-phase carriers to generate the in-phase and quadrature-phase channel set, separate sets of sinusoids could be used to independently generate the in-phase and quadrature-phase channel sets, with the second set of carriers offset from the first set by 90°. For example,

the D_Q data could be applied to the second set of carrier sinusoids where the D_Q in-phase (PNI) spread data is applied to $\cos(\omega_c t - 90^\circ)$ and the D_Q quadrature-phase (PNQ) spread data is applied to $\sin(\omega_c t - 90^\circ)$. The resulting signals are then summed to produce the quadrature-phase channel set 92, which in turn are summed with the in-phase channel set 90.

The use of the Walsh_S channels as set forth in Table I. also allows simplified implementation of the supplemental channel within quadrature-phase channel set 92. In particular, the use of the Walsh_S codes listed in Table I allows the supplemental channel to use whole subsets of 64 symbol Walsh_i codes without the need to generate each and everyone of those Walsh codes.

For example, when $N = 5$ the Walsh_S codes specified by Table I allocate a set of 32 64-symbol Walsh_i codes for the supplemental channel. That is, all the even-indexed 64-symbol Walsh codes or all of the odd-indexed 64-symbol Walsh codes are allocated for the supplemental channel. This leaves the odd-indexed or even-index channels, respectively, for implementing the extended IS-95 traffic channel set. In FIG. 3, the supplemental channel uses the odd 64-symbol Walsh code channels when Walsh_S = {+,-} and the even channels are available for the extended IS-95 traffic channel set.

In another example, when $N = 4$, the associated Walsh_S codes allocate a set of sixteen 64-symbol Walsh_i codes. This leaves a set of forty-eight remaining Walsh_i codes for implementing the extended IS-95 traffic channels or for implementing additional supplemental channels. In general, the use of the Walsh_S code that corresponds to a particular value N allocates 2^N 64-symbol Walsh_i codes for the supplemental channel using only a single, and shorter, Walsh_S code.

The allocation of whole subsets of Walsh_i codes using a single Walsh_S code is facilitated by even distribution the 64-symbol Walsh_i codes within the subset. For example, when $N = 5$ the Walsh_i codes are separated by 2, and when $N = 4$ the Walsh_i codes are separated by 4. Only by providing a complete set of quadrature-phase channels 92 for implementing the supplemental channel can the allocation of large set of evenly spaced Walsh_i channels be performed, and therefore implemented using a single Walsh_S code.

Also, allocating a subset of 64-symbol Walsh_i codes using a single shorter Walsh_S code reduces the complexity associated with providing a high-rate supplemental channel. For example, performing actual modulation using the set of 64-symbol Walsh_i codes, and summing of the resulting modulated data would require a substantial increase in signal

processing resources when compared with the use of the single Walsh_s generator used in the implementation of the invention described herein.

Sets of evenly spaces Walsh_i channels could not be allocated as easily if the supplemental channel were placed in the in-phase channel set 90 of the previously existing IS-95 forward link, or in the in-phase and quadrature-phase channels with QPSK modulation. This is because certain sixty-four symbol Walsh_i channels are already allocated for control functions such as the paging, pilot, and sync channels on the in-phase channel. Thus, using a new quadrature-phase Walsh code space allows for simplified implementation of the supplemental channel.

Also, the use of the a single Walsh_s code improves the performance of the high-rate supplemental channel because the variance in the amplitude of the supplemental channel is minimized. In the embodiment described herein, the amplitude is simply based on the positive or negative integer associated with the Walsh_s code. This is in contrast to performing the modulation with a set of 2^N 64-symbol Walsh_i codes, which would result in the set of amplitudes 0, +2, -2, +4, -4, ..., 2^N , and -2^N .

Among other improvements, reducing the variance in the amplitude reduces the peak-to-average power ratio, which increases the range at which the forward link signal can be received for a given maximum transmit power of the base station 12, or other forward link transmit system.

FIG. 5 is a block diagram of the supplemental channel system 132 of FIG. 1 when configured in accordance with one embodiment of the invention. User data is received by CRC checksum generator 200 which adds checksum information to the data received. In the preferred embodiment of the invention, the data is processed in 20 ms frames as is performed for IS-95, and 16 bits of checksum data is added. Tail bits 202 adds eight tail bits to each frame. The output of tail bits 202 is received at a data rate D by convolutional encoder 204 which performs convolutional encoding at rate R_c on each frame. R_c differs for different embodiments of the invention as described in greater detail below.

Block interleaver 206 interleaves the code symbols from convolutional encoder 204 and repeater 208 repeats the code symbol sequence from interleaver 206 by a repeat amount M. The repeat amount M varies in different embodiments of the invention, and will typically depend on the coding rate R_c and the supplemental channel rate R_s (see FIG. 3). The repeat amount is discussed further below. Mapper 210 receives the code symbols from repeater 208 and converts the logic zeros and logic ones into

positive and negative integer values which are output at the supplemental channel rate R_s .

Table II provides a list of data input rates D , encoding rates R_c , repeat amounts M , and supplemental channel rates R_s that can be used in different 5 embodiments of the invention. In some embodiments multiple rates are used.

Convolutional Encoder Input Rate (D) kbps	(N)	Walsh Channels for Supp. Channel (2^N)	Convolutional Code Rate (R_c)	Repetition Amount (M)	Walsh Symbols/Code Symbols (W/S)	Convolutional Encoder Input Bits	Number of Channel Bits per Frame
38.4	2	4	$1/2$	1	16/1	768	1,536
38.4	3	8	$1/4$	1	8/1	768	3,072
38.4	4	16	$1/4$	2	4/1	768	6,144
38.4	5	32	$1/4$	4	2/1	768	12,288
38.4	6	64	$1/4$	8	1/1	768	24,576
76.8	3	8	$1/2$	1	8/1	1,536	3,072
76.8	4	16	$1/4$	1	4/1	1,536	6,144
76.8	5	32	$1/4$	2	2/1	1,536	12,288
76.8	6	64	$1/4$	4	1/1	1,536	24,576
153.6	4	16	$1/2$	1	4/1	3,072	6,144
153.6	5	32	$1/4$	1	2/1	3,072	12,288
153.6	6	64	$1/4$	2	1/1	3,072	24,576

Table II.

10 Three encoder input rates D for the supplemental channel are shown: 38.4, 76.8, and 153.6 kilobits per second. For each of these encoder input rates D , a set of encoder rates R_c , N values, and repeat amounts M are provided which achieve the desired encoder input rate D . Additionally, the ratio of Walsh_s symbols to code symbols is provided, which corresponds to the 15 length of the Walsh_s code. Also, the number of encoder input bits per 20 frame is provided, as is the number of code symbols transmitted per 20 ms frame. The actual data transmission rate will be equal to the encoder input rate D , less the overhead necessary for the CRC bits and tail bits and any other control information provided. The use of Reed-Soloman encoding in 20 addition to, or instead of, CRC checksum encoding is also contemplated.

In general, it is desirable to use the largest value of N possible for the supplemental channel in order to spread the supplemental channel over the greatest number of Walsh_i channels. Spreading the supplemental channel out over a larger set of Walsh_i channels minimizes the effect of inter- 25 channel interference between the two corresponding Walsh_i channels on the in-phase channel set 90 and the quadrature-phase channel set 92. This inter-channel interference is created by imperfect phase alignment

experienced during receive processing. By spreading out the supplemental channel over a larger set of Walsh_i channels, the amount of inter-channel interference experience for any particular Walsh_i channel in the in-phase channel set 90 is minimized, because the portion of the supplemental channel in that Walsh_i channel is small. Also, spreading the supplemental channel over a larger set of Walsh_i channels with a larger total channel symbol rate allows for a higher symbol diversity, which improves performance in fading channel conditions.

When the number of Walsh channels needed for the desired encoder input rate D using rate 1/2 encoding is less than the number of available Walsh channels by at least a factor of two, performance is improved by spreading the signal over more Walsh channels. The higher channel symbol rate for the larger number of Walsh channels is obtained by using a rate 1/4, rather than a rate 1/2, code, or by sequence repetition, or both. The rate 1/4 code provides additional coding gain over that of a rate 1/2 code in benign and fading channel conditions and the sequence repetition provides improved performance in fading channel conditions due to the increased diversity.

In a preferred embodiment of the invention, a supplemental channel having an encoder input rate of 76.8 kilobits per second is provided using $N = 5$, an encoder rate R_c of 1/4, and a repetition amount of $M = 2$. Such an implementation provides data transfer rates on the order of an ISDN channel including sufficient bandwidth for signaling. Also, using $N = 5$ maintains 32 additional Walsh_i channels for providing extended IS-95 channels.

The actual sustainable transmission rate of the supplemental channel will vary depending on a variety of environmental conditions including the amount of multipath experienced by the forward link transmission. The supplemental transmission rate depends of the amount of multipath because forward link signals that arrive via different paths are no longer orthogonal and therefore interfere with one another. This interference increases with increased transmission rates because of the additional transmit power necessary. Thus, the more multipath interference experienced, the less the sustainable transmission rate of the supplemental channel. Therefore, a lower transmission rate for the supplemental channel is preferred for high multipath environments.

In one embodiment of the invention, a control system that measures the various environmental factors and which selects the optimal supplemental channel processing characteristics is contemplated. Also, the

use of signal cancellation is contemplated for removing noise due to multipath transmissions. A method and apparatus for performing such noise cancellation is described in copending US patent application serial no. 08/518,217 entitled "METHOD AND SYSTEM FOR PROCESSING A
5 PLURALITY OF MULTIPLE ACCESS TRANSMISSIONS" assigned to the assignee of the present invention and incorporated herein by reference.

FIG. 6 is a block diagram of a receive processing system for processing the high-rate supplemental channel in accordance with one embodiment of the invention. Typically, the receive processing system will be implemented
10 in a subscriber unit 10 of a cellular telephone system.

During operation, RF signals received by antenna system 300 are downconverted with in-phase carrier 302 and quadrature-phase carrier 304 generating digitized in-phase receive samples R_I and quadrature-phase receive samples R_Q . These receive samples are provided to the finger
15 processor module shown and to other finger processors (not shown) in accordance with the use of a rake receiver. Each finger processor processes one instance of the supplemental forward link signal received, with each instance generated by multipath phenomena.

The in-phase and quadrature-phase receive samples R_I and R_Q are
20 multiplied with the complex conjugate of the PN spreading codes generated by in-phase spreading code generator 306 and quadrature-phase spreading code generator 308 yielding receive terms Y_I and Y_Q . The receive terms Y_I and Y_Q are modulated with the Walsh_s code generated by Walsh generator 310, and the resulting modulated data is summed over the number of
25 Walsh symbols in the Walsh_s code by summers 312. Additionally, the receive terms Y_I and Y_Q are summed and filtered (averaged) by pilot filters 316.

The outputs of summers 312 are then multiplied with the complex conjugate of the filter pilot data, and the resulting quadrature-phase term is
30 used at the supplemental channel soft-decision data 320. Supplemental soft-decision data 320 can then be combined with soft-decision data from other finger processors (not shown) and the combined soft-decision data decoded.

FIG. 7 is a block diagram of decoder system used to decode the supplemental soft-decision data 320 in accordance with one embodiment of
35 the invention. The soft-decision data is received by accumulator 400 which accumulates samples of the soft-decision data by the repeat amount M . The accumulated data is then deinterleaved by block deinterleaver 402 and decoded by trellis decoder 404. Various types of decoders are well known including Viterbi decoders.

The user data in the hard-decision data from trellis decoder 404 is then checked with the CRC checksum data by CRC check system 406, and the resulting user data is output along with check results indicating whether the user data was consistent with the check sum data. The receive processing system or user can then determine whether to use the user data based on the CRC checksum results.

Thus, a high data rate transmission system particularly suited for use in conjunction with the IS-95 forward link has been described. The invention can be incorporated into both terrestrial as well as satellite based wireless communication systems, as well as wire based communication systems over which sinusoidal signals are transmitted such as coaxial cable systems. Also, while the invention is described in the context of a 1.2288 MHz bandwidth signal, the use of other bandwidths is consistent with the operation of the invention including 2.5 MHz and 5.0 MHz systems.

Similarly, while the invention is described using transmission rates on the order of 10 kbps and 70 kbps, the use of other channel rates may be employed. In a preferred embodiment of the invention, the various systems described herein are implemented using semiconductor integrated circuits coupled via conduct, inductive, and capacitive connections, the use of which is well known in the art.

The previous description 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 (WE) CLAIM:



CLAIMS

1. A telecommunications system for conducting a high-rate
communication in conjunction with a set of medium rate communications
using code division multiple access radio frequency signal processing
comprising:

first signal processing means for transmitting the set of medium rate
communications over a first set of medium rate channels in a radio
frequency bandwidth; and

second signal processing means for transmitting the high-rate
communication over a second set of medium rate channels in said radio
frequency bandwidth, wherein said second set of medium rate channels is
orthogonal to said first set of medium rate channels.

2. The telecommunications system as set forth in claim 1 wherein
said first set of medium rate channels is defined by a first set of channel
codes, and said second set of medium rate channels is defined by a second set
of channel codes, and the high-rate communication is transmitted over an
evenly distributed subset of said second set of channel codes.

3. The telecommunications system as set forth in claim 1
wherein:

said first signal processing means is further for generating said set of
medium rate channels using a corresponding set of long channel codes; and

said second signal processing means is further for generating a high-
rate channel with a short channel code.

4. The telecommunications system as set forth in claim 3 wherein
said high-rate communication is comprised of a set of high-rate code
symbols, and each high-rate code symbol is modulated with an instance of
said short channel code.

5. The telecommunications system as set forth in claim 1 wherein
set first set of channel codes and set second set of channel codes are sixty-four
symbol Walsh codes.

6. The telecommunications system as set forth in claim 2 further
comprising:



third signal processing means for transmitting a second set of
4 medium communications using another subset of said second set of
medium rate channels.

7. The telecommunications system as set forth in claim 1 wherein
2 said first set of medium rate channels are transmitted in an in-phase
channel and said second set of medium rate channels are transmitted in a
4 quadrature-phase channel.

8. The telecommunications system as set forth in claim 3 wherein
2 said first signal processing means further comprises:

summer for generating summed data in response to said first set of
4 medium rate channels;

first spreader means for generating first spread data in response to said
6 summed data; and

second spreader means for generating second spread data in response
8 to said high-rate channel.

9. The telecommunications system as set forth in claim 3 further
2 comprising:

first in-phase spreader means for generating first in-phase spread data
4 in response to said summed data;

first quadrature-phase spreader means for generating first quadrature-
6 phase spread data in response to said high-rate channel;

second in-phase spreader means for generating second in-phase
8 spread data in response to said high-rate channel;

second quadrature-phase spreader means for generating second
10 quadrature-phase spread data in response to said high-rate channel; and

first summer means for generating an in-phase term in response to
12 said first in-phase spread data and a negative instance of said second
quadrature-phase spread data; and

14 second summer means for generating an quadrature-phase term in
response to said first quadrature-phase spread data and said second in-phase
16 spread data.

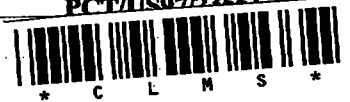
10. The telecommunications system of claim 9 further comprising:
2 in-phase carrier generator for modulating said in-phase term; and
quadrature phase carrier generator for modulating said quadrature-
4 phase term.





11. A method for transmitting data using a radio frequency signal
2 comprising the steps of:
- a) generating a set of channels using a set of long Walsh codes;
 - 4 b) generating a high-rate channel using a short Walsh code;
 - c) transmitting said set of channels via a first carrier; and
 - 6 d) transmitting said high-rate channel via a second carrier that is
orthogonal to said first carrier.
12. The method as set forth in claim 11 further comprising the
2 steps of:
- modulating a first instance of said set of channels with an in-phase
4 pseudorandom noise code and an in-phase carrier;
 - modulating a second instance of said set of channels with a
6 quadrature-phase pseudorandom noise code and a quadrature-phase carrier;
and
 - 8 summing said first instance of said set of channels with said second
instance of said set of channels.
13. The method as set forth in claim 12 further comprising the
2 steps of:
- modulating a first instance of said high-rate channel with an in-phase
4 pseudorandom noise code and an in-phase carrier;
 - modulating a second instance of said high-rate channel with a
6 quadrature-phase pseudorandom noise code and a quadrature-phase carrier;
inverting said second instance of said high-rate channel; and
 - 8 summing said first instance of said high-rate channel with said
second instance of said high-rate channel.
14. The method as set forth in claim 11 further comprising the step
2 of transmitting pilot data on one channel from said set of channels.
15. The method as set forth in claim 10 wherein said set of
2 channels includes a pilot channel, a synchronization channel and a traffic
channel.
16. The method as set forth in claim 11 wherein said short code
2 occupies a set of evenly spaced long Walsh codes.





17. The method as set forth in claim 10 wherein said long Walsh
2 codes are comprised of sixty-four Walsh symbols.

18. A telecommunications system for transmitting data over code
2 division multiple access radio frequency signals comprising:
first channel generation system for generating a set of medium
4 rate channels; and
second channel generation system for generating a high speed
6 channel that is orthogonal to the set of medium rate channels.

19. The telecommunications system of claim 18 wherein said first
2 channel generation system is comprised of a set of long channel code
modulators.

20. The telecommunications system of claim 19 wherein said
2 second channel generation system is comprised of a short channel code
modulator.

21. The telecommunications system as set forth in claim 18
2 wherein said second channel generation system comprises a means for
transmitting data via a set of evenly distributed long code channels.

22. A method for operating a multichannel communication
2 system using direct sequence spread spectrum signal processing comprising
the steps of:

- 4 a) generating a complex data source having a multichannel
term and a high-rate term;
- 6 b) generating a complex spreading code having an in-phase
term and quadrature-phase term;
- 8 c) complex multiplying complex data source and said
complex spreading code yielding a real term and an imaginary term;
- 10 d) modulating said real term with an in-phase carrier; and
e) modulating said imaginary term with a quadrature-
- 12 phase carrier.

23. The method as set forth in claim 22 wherein step a) is
2 comprised of the steps of:

- a.1) generating a set of medium rate channels in response to a set of
4 medium rate data sources and a set of long channel codes;





a.2) generating said multichannel term by summing said set of
6 medium rate channels; and

a.3) generating a high-rate channel in response to a high-rate data
8 source and a short channel code.

24. The method as set forth in claim 23 wherein step a.1) is
2 comprised of the step of modulating said set of medium rate data sources
with said set of channel codes.

25. The method as set forth in claim 23 further comprising the step
2 of adjusting the amplitude of said set of medium rate channels and said
high-rate channel.

26. The method as set forth in claim 23 wherein step a.3) is
2 comprised of the step of transmitting said high-rate data over a set of
medium rate channels.

27. The method as set forth in claim 23 further comprised of the
2 step of a.3) is comprised of the steps of:

generating a second set of medium rate channels in response to a
4 second set of medium rate channels and a second set of long channel codes;
and

6 summing said second set of medium rate channels with said high-
rate channel.

28. A direct sequence spread spectrum communications system
2 comprising:

first long channel code modulator for generating first channel
4 data in response to first user data;

first short channel code modulator for generating second
6 channel data in response to second user data;

first in-phase spreader for generating first in-phase data in
8 response to said first channel data;

second in-phase spreader for generating second in-phase data in
10 response to said second channel data;

first quadrature-phase spreader for generating first quadrature-
12 phase data in response to said first user data;

second quadrature-phase spreader for generating second quadrature-
14 phase data in response to second user data;

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- first summer for generating an in-phase term in response to
- 16 said first in-phase data and an inverted instance of said second quadrature-phase user data;
- 18 second summer for generating a quadrature-phase term in response to said first quadrature-phase data and said second in-phase data;
- 20 in-phase carrier sinusoid modulator for generating an in-phase signal in response to said first term;
- 22 quadrature-phase carrier sinusoid modulator for generating a quadrature-phase signal in response to said second term; and
- 24 summer for summing said in-phase signal and said quadrature-phase signal.

29. The system as set forth in claim 28 wherein said first channel

2 has a lower data rate than said second channel.

30. A method for transmitting a high data rate channel in

2 conjunction with a set of medium rate communications using code division multiple access processing comprising the steps of:

- 4 a) generating an in-phase set of medium rate channels;
- b) generating a quadrature-phase set of medium rate channels;
- 6 c) transmitting said set of high data rate channel over said in-phase set of medium rate channels; and
- 8 d) transmitting said high-rate communication over a subset of said quadrature-phase set of medium rate channels.

31. The method as set forth in claim 30 wherein said subset is

2 comprised of a set of evenly space Walsh channels.

32. The method of claim 30 wherein steps a) is comprised of the

2 step of:

- generating said set of channels by modulating said set of medium rate
- 4 communications with a set of long channel codes;
- summing said set of channels yielding summed data;
- 6 generating in-phase spread data in response to said summed data and an in-phase spreading code;
- 8 generating quadrature-phase spread data in response to said summed data and a quadrature-phase spreading code;
- 10 modulating said in-phase spread data with an in-phase carrier yielding an in-phase signal;





- 12 modulating said quadrature-phase spread data with a quadrature-
phase carrier yielding a quadrature-phase signal; and
14 summing said in-phase signal and said quadrature phase signal.

33. The method of claim 30 wherein steps b) is comprised of the
2 step of:

- generating said high-rate channel by modulating said high-rate
4 communication with a short channel code;
generating high-rate in-phase spread data in response to said high-rate
6 channel and said in-phase spreading code;
generating high-rate quadrature-phase spread data in response to said
8 high-rate data and a quadrature-phase spreading code;
modulating said high-rate in-phase spread data with an quadrature-
10 phase carrier yielding an high-rate quadrature-phase signal;
modulating an inverted instance of said high-rate quadrature-phase
12 spread data with an in-phase-phase carrier yielding a high-rate in-phase-
phase signal; and
14 summing said high-rate in-phase signal and said high-rate quadrature
phase signal.

34. The method of claim 30 wherein steps a) and b) are comprised
2 of the steps of:

- a.1) modulating said set of medium rate communications using a
4 set of channel codes;
a.2) summing said set of channel codes yielding summed data;
6 a.3) modulating said summed data with a first set of carrier
sinusoids;
8 b.1) modulating said high-rate channel with a short channel code
yielding said high-rate channel; and
10 b.2) modulating said high-rate channel with a second set of carrier
sinusoids that are 90° out of phase with said first set of carrier sinusoids.

35. The method as set forth in claim 34 wherein said short channel
2 code is comprised of two Walsh symbols and said long channel codes are
each comprised of sixty-four Walsh symbols.

