(12) PATENT
(19) AUSTRALIAN PATENT OFFICE

(11) Application No. **AU 199944557 B2**
(10) Patent No. **727342**

(54) Title
CDMA system

(51)[6] International Patent Classification(s)
H04B 007/216 H04Q 007/30
H04J 013/00 H04Q 007/32

(21) Application No: 199944557 (22) Application Date: 1999.08.18

(30) Priority Data

(31) Number	(32) Date	(33) Country
EP98306720	1998.08.21	GB

(43) Publication Date : 2000.03.23
(43) Publication Journal Date : 2000.03.23
(44) Accepted Journal Date : 2000.12.14

(71) Applicant(s)
Lucent Technologies Inc

(72) Inventor(s)
Stephan ten Brink

(74) Agent/Attorney
SPRUSON and FERGUSON,GPO Box 3898,SYDNEY NSW 2001

(56) Related Art
DE 19717546
EP 818901

CDMA SYSTEM

ABSTRACT OF THE DISCLOSURE

The invention concerns a CDMA system, including a transmitter (10) and receiver (20), for use in e.g. a digital wireless communications system and in particular to a method of and apparatus for mapping and demapping CDMA signals. The CDMA system comprises a transmitter (10) and a receiver (20). The transmitter (10) includes an encoder (11) and a bit interleaver (12) for processing said CDMA signal to be transmitted, a mapper (14) connected in series with the encoder (11) and bit interleaver (12) and means for transmitting said processed CDMA signal. The receiver (20) comprises means for receiving said transmitted CDMA signal, a bit deinterleaver (26) and a decoder (27) for processing said received CDMA signal and a demapper (24) connected in series with the bit deinterleaver (26) and decoder (27). Iterative demapping may be performed in the receiver (20) by passing back the output of the decoder to the demapper (24). A corresponding method is also disclosed.

S & F Ref: 470615

AUSTRALIA

PATENTS ACT 1990

COMPLETE SPECIFICATION

FOR A STANDARD PATENT

ORIGINAL

Name and Address of Applicant: Lucent Technologies Inc
600 Mountain Avenue
Murray Hill New Jersey 07974-0636
UNITED STATES OF AMERICA

Actual Inventor(s): Stephan ten Brink

Address for Service: Spruson & Ferguson, Patent Attorneys
Level 33 St Martins Tower, 31 Market Street
Sydney, New South Wales, 2000, Australia

Invention Title: CDMA System

The following statement is a full description of this invention, including the best method of performing it known to me/us:-

CDMA SYSTEM

The invention relates to a CDMA system, including a transmitter and receiver, for use in e.g. a digital wireless communications system. In particular, the invention relates to a method of and apparatus for mapping and demapping CDMA signals.

Recently iterative decoding algorithms have become a vital field of research in digital communications. The first discovered and still most popular encoding scheme suited for iterative decoding is the parallel concatenation of two recursive systematic convolutional codes, also referred to as 'Turbo Codes', as described in J. Hagenauer, "The Turbo Principle: Tutorial Introduction and State of the Art", Symposium on Turbo Codes, Brest, France, September 1997. In the past few years other applications of the 'Turbo Principle' have been found e.g. G. Bauch, H. Khorram, J. Hagenauer, "Iterative Equalization and Decoding in Mobile Communications Systems", in Proc. EPMCC'97, Bonn, pp. 307-312, Germany, October 1997.

Channel coding is used to make the transmitted digital information signal more robust against noise. For this the information bit sequence is encoded at the transmitter by a channel encoder and decoded at the receiver by a channel decoder. In the encoder, redundant information is added to the information bit sequence in order to facilitate error correction in the decoder. For example, in a systematic channel encoding scheme the redundant information is added to the information bit sequence just as additionally inserted, 'coded' bits. In a non-systematic encoding scheme the outgoing bits are all coded bits, and no 'naked' information bits remain. The number of incoming bits (information bits) at the encoder is smaller than the number of outgoing bits (information bits plus inserted coded bits, or all coded bits). The ratio of incoming/outgoing bits is called the 'code rate R' (typically R=1/2).

Concatenated coding schemes apply to at least two parallel or serially concatenated encoders. There are iterative decoding algorithms for either parallel or serially concatenated coding systems and the classical 'Turbo' Codes are parallel concatenated codes.

Fig. 1 shows a genuine serially concatenated coding scheme with the transmission performed on a block-by-block basis. The signal sequence is encoded twice at the transmitter in a serial manner. The binary signal from the digital source (e.g. an analogue to digital converter with analogue input signal from a microphone) is first encoded by an outer encoder. The output of the outer encoder gets passed through an interleaver which changes the order of the incoming bit symbols to make the signal appear more random to the following processing stages. After the interleaver the signal is encoded a second time by an 'inner encoder'. Correspondingly, at the receiver the signal is first decoded by the inner decoder, deinterleaved, and decoded by the outer decoder. From the outer decoder soft values are fed back as additional 'a priori' input to the inner decoder. The soft values are reliability values of the quality of the decoded signal. The feedback of these values helps to reduce the bit error rate of the hard decision values 0,1 at the output of the outer decoder in further, iterative decoding steps. The iterative decoding of a particular transmitted sequence is stopped with an arbitrary termination criterion, e.g. after a fixed number of iterations, or until a certain bit error rate is reached (the termination criterion is not important at all for the invention). It should be noted that the 'a priori' soft value input to the inner decoder is set to zero for the very first decoding of the transmitted bit sequence ('0^{th} iteration').

The inner and outer binary codes can be of any type: Systematic, or non-systematic, block or convolutional codes.

At the receiver the two decoders are soft-in/soft-out decoders (SISO-decoder). A soft value represents the reliability of the bit decision of the respective bit symbol (whether 0 or 1). A soft-in decoder accepts soft reliability values for the incoming bit symbols. A soft-out decoder provides soft reliability output values on the outgoing bit symbols. The soft-out reliability values are usually more accurate than the soft-in reliability values since they can be improved during the decoding process based on the redundant information that is added with each encoding step at the transmitter.

Method and apparatus for iteratively demapping a signal is described in European Patent Application number 98302653.5 filed on 3 April 1998, the contents of which are incorporated herein by reference.

CDMA (Code Division Multiple Access) systems have a plurality of users separated by different codes. Each transmitted bit of a user k is substituted by a number N_c of 'shorter' bits, called 'chips', which are chosen according to the 'channelization code' of the particular user k. Since the occupied bandwidth expands by a factor of N_c after the 'substitution', this process is called 'spreading', and a CDMA system is often referred to as 'spread spectrum system'. After spreading, the signal for each user occupies the total available bandwidth B. At the receiver the desired user is detected by means of correlation with the appropriate channelization code.

Multicode CDMA is a method that provides higher data rates to a single user in a CDMA system. The particular user is assigned N channelization codes, instead of having only one in a conventional CDMA system. Hence the 'multicode' user can transmit at an N times higher data rate than a 'single-code' user. The N binary antipodal codes are added up at the multicode transmitter to form a N+1-level amplitude modulated signal, instead of a binary antipodal signal for the single code case.

Fig. 2 shows a conventional multicode CDMA (M-CDMA) single user transmitter/receiver. The binary signal from the digital source (e.g. an analogue to digital converter with analogue input signal from a microphone) is first encoded by the channel encoder. The output of the channel encoder gets passed through an interleaver which changes the order of the incoming bit symbols to make the signal appear more random to the following processing stages. After the interleaver the coded bit stream is split into N parallel bit streams by a demux (serial to parallel conversion). Each bit stream 1,...,N gets spread (i.e. multiplied) by a binary antipodal channelization code (codeword 1,...,N) of length N_C chips. Typically, the N channelization codes are orthogonal. After spreading the N binary antipodal chip streams are added up on the chip rate to form the amplitude modulated (N+1 levels) chip symbols. Hence N coded bit symbols result in N_C chip symbols. Each block of N_C chip symbols is referred to as a composite multicode CDMA symbol. Optionally, scrambling on the chip rate can be applied to even further randomise the signal. Typically the scrambling sequence is a binary antipodal pseudo-random sequence. The composite signal is then put to the transmission channel.

Figure 2 shows base band processing only and up-conversion to radio frequency etc. is omitted for the sake of clarity. For simplicity of the description we assume a real signal processing. However, the real channelization codes could be complex channelization codes as well, or there could be a complex scrambling sequence.

On the channel the signal is distorted by additive noise, or any other noise form.

Correspondingly, at the receiver the signal is descrambled (optionally) and correlated with the N channelization codes (codewords 1,...,N). The correlation consists of a multiplication with the respective channelization code and an accumulation over N_c chips. After multiplexing (parallel to serial conversion) and deinterleaving the N correlation results are put to the channel decoder. Finally, the information bits are available at the output of the decoder, or the hard decision device respectively.

The conventional CDMA and M-CDMA system as described above does not allow for bit error rate (BER) reduction e.g. though iterative decoding. There is thus a requirement for a CDMA or M-CDMA system in which an improved BER may be achieved.

In accordance with one aspect of the present invention, there is provided a CDMA system comprising a transmitter and a receiver, the transmitter comprising a first encoder for encoding a signal, an interleaver for interleaving the encoded signal, and a second encoder for further encoding the interleaved signal,

the second encoder comprising a mapper means for mapping components of the interleaved signal to components of a desired mapped signal, whereby the mapped signal components are dependent on the components of the interleaved signal,

and spreading means for spreading each mapped component with a respective orthogonal spreading code,

and the receiver including despreading means for multiplying the received signal with said orthogonal spreading codes to provide components of the received signal,

a demapper means for reversing said mapping and for estimating the likely value of the received signal components,

a deinterleaver for deinterleaving the estimated component values, being coupled to a decoder means for decoding the encoding provided by said first encoder, and

a feedback path from the decoder to the demapper means including an interleaver, to enable the receiver to perform iterative decoding.

In accordance with another aspect of the present invention, there is provided a transmitter for a CDMA system, comprising:

AUSTRALIAN PATENT OFFICE

a first encoder for encoding a signal, an interleaver for interleaving the encoded signal, and a second encoder for further encoding the interleaved signal, the second encoder comprising a mapper means for mapping components of the interleaved signal to mapped components of a mapped signal, whereby the mapped signal components are dependent on the components of the interleaved signal, and spreading means for spreading each mapped component with an orthogonal spreading code.

In accordance with another aspect of the present invention, there is provided a receiver for a CDMA system, for receiving a serially encoded signal having a first encoding followed by an interleaving and a second encoding with a mapping and orthogonal spreading codes, the receiver comprising:

despreading means for multiplying the received signal with said orthogonal spreading codes to provide components of the received signal,

a demapper means for reversing said mapping and for estimating the likely value of the received signal components,

a deinterleaver for deinterleaving the estimated values of the received signal components,

a decoder for decoding the first encoding of the received signal, and

a feedback path from the decoder to the demapper means, including an interleaver, to enable the receiver to perform iterative decoding.

In the receiver iterative demapping is performed by passing back the output of the decoder to the demapper. The system may be a multi-user CDMA system, in which case the N parallel channelization codes are regarded as the channelization codes of at most N different users. The system may be a multicode CDMA system in which case the N channelization codes belong to at least one user.

In accordance with another aspect of the present invention, there is provided a method of transmitting a CDMA signal, comprising:

performing a first encoding of a signal, interleaving the encoded signal, and performing a second encoding of the interleaved signal,

the second encoding including a mapping of components of the interleaved signal to mapped components of a mapped signal, whereby the mapped signal components are dependent on the components of the interleaved signal, and

spreading each mapped component with an orthogonal spreading code.

In accordance with another aspect of the present invention, there is provided a method of receiving a CDMA signal, comprising:

AUSTRALIAN PATENT OFFICE

receiving a serially encoded signal having a first encoding followed by an interleaving and a second encoding with a mapping and orthogonal spreading codes,

performing a despreading of the received signal by multiplying the received signal with said orthogonal spreading codes to provide components of the received signal,

demapping the received signal, including reversing and mapping and estimating the likely value of the received signal components,

deinterleaving the estimated values of the received signal components,

decoding said first encoding of the received signal, and

feeding back the decoded values as a priori knowledge to said demapping, to enable iterative decoding.

The CDMA signal is iteratively demapped by iterating the bit deinterleaving, decoding and demapping steps.

By inserting a mapper between demultiplexer and orthogonal spreading of the N parallel CDMA channels of a conventional transmitter, a bit error rate reduction through iterative decoding can be achieved at the receiver. For this, the receiver has to perform a demapping operation after the despreading. The demapper can make use of a priori knowledge gained by the channel decoder that enables iterative demapping and decoding.

The 'modified' mapping can be arbitrary and just needs to be different from the 'identical' mapping. However, the achievable performance gains strongly depend on the chosen 'modified' mapping. The mapper does not add redundancy to the

AUSTRALIAN PATENT OFFICE

signal and can be interpreted as a rate one binary block encoder in combination with orthogonal CDMA spreading. However, the spreading does not have to be orthogonal.

Iterative demapping and decoding reduces the bit error rate of multicode CDMA links that use plain channel coding.

Iterative demapping and decoding for CDMA works as long as there is at least one bit symbol interleaver between encoder and the spreading/mapping.

Since the orthogonality of the spreading codes is preserved, this method is suited, e.g., for synchronous multi-user down-link communication in a wireless communication link (base station to mobile terminal, multi-user transmitter), as well as for asynchronous up-link communication (mobile terminal to base station, single user transmitter).

An embodiment of the invention is described below and with reference to the following figures in which:

Figure 1 shows a transmitter and receiver using a serially concatenated coding scheme;

Figure 2 shows a conventional multicode CDMA (M-CDMA) single user transmitter and receiver.

Figure 3 shows a multicode CDMA (M-CDMA) single user transmitter and receiver according to the invention.

At the transmitter 10 of figure 3, the binary random signal gets convolutionally encoded 11 and fed to a random bit interleaver 12 which interleaves the bit symbols (any channel code can be used and any code rate, not only convolutional codes). After the interleaver the coded bit stream is split into N parallel bit streams by a demux 13 which performs serial to parallel conversion.

The mapper 14 performs a N bit to N bit mapping operation. After mapping, each bit stream 1,...,N gets spread (i.e. multiplied by multipliers 15_1 to 15_N) by a binary antipodal channelization code (codeword 1,...,N) of length N_C chips. Typically, the N channelization codes are orthogonal. After spreading the codewords are added up by adder 16 on the chip-rate. Optionally a binary antipodal scrambling sequence can be applied (17) to even further randomise the signal.

On the channel, the symbols are distorted by additive noise (illustrated by adder 18), or any other noise forms.

At the receiver 20 the signal gets descrambled 21 (optional) and correlated with the N channelization codes (codewords 1,...,N). The correlation consists of a multiplication by multipliers 22_1 to 22_N with the respective channelization code and an accumulation over N_C chips at accumulators 23_1 to 23_N. The N correlation results are utilised by the demapper 24 to calculate log-likelihood ratios (also referred to as L-values) of the transmitted coded bits $x_{0,...,N-1}$ of the N multicode CDMA channels.

The log-likelihood ratio values are multiplexed at multiplexer 25, deinterleaved by bit deinterleaver 26 and put to the A Posteriori Probability calculator 27 (APP), or any other SISO-decoder. After the decoding the estimates on the transmitted information bits are available at the output of the hard decision device by taking the sign of the APP-soft output values for the information bits.

In the iterative demapping/decoding path the 'extrinsic information' is passed through the bit interleaver 28 and fed back as a priori knowledge to the demapping device 24 at input 29. The 'extrinsic' information is the difference of the soft input/soft output values at the decoder and depicts the new, statistically independent information (at least for the first iteration) gained by the decoding process. The demapping device can utilise the a priori knowledge from the decoder to refine its output for further iterative decoding steps.

Note that the iterative decoding is performed on the bit-rate rather than the chip-rate, and thus it is of low complexity.

For simplicity, the following description, assumes real signal processing, a single propagation path, and additive noise. The extension to complex signal processing, multipath propagation and other noise forms is straightforward. The signal processing for one particular composite multicode CDMA symbol $\mathbf{z}$ (vector with N_c elements) is considered.

Note: boldface denotes vectors.

At the transmitter:

The N:N-mapper performs a mapping of N coded bits (vector $\mathbf{x}$) to the mapped coded bit vector $\mathbf{x}_M = map(\mathbf{x})$, $\mathbf{x} = (x_0,...,x_{N-1})$,

$$\mathbf{x}_M = \left(x_{M,0},\ldots,x_{M,N-1}\right); x_l,\ x_{M,l} \in \{-1,+1\}$$

The bit vectors $\mathbf{x}$, $\mathbf{x}_M$ are interpreted as integer numbers with values ranging from 0 to $2^N - 1$ and calculated, e.g. for $\mathbf{x}$ as $\sum_{l=0}^{N-1} \frac{\left(x_l + 1\right)}{2} \cdot 2^l$ (for $\mathbf{x}_M$ respectively), then an arbitrary mapping for N=3 might be defined by:

input $\mathbf{x}$	mapped output $\mathbf{x}_M$
0	5
1	2
2	7
3	1
4	0
5	6
6	3
7	4

After mapping, an orthogonal spreading with Walsh-code matrix $\mathbf{W} = (\mathbf{w}_0, \ldots, \mathbf{w}_{N-1})$ and scrambling with sequence $\mathbf{s}$ is performed. The transmitted signal is

$$\mathbf{y} = (\mathbf{x}_M \cdot \mathbf{W}) \circ \mathbf{s}$$

In which:

row-vectors $\mathbf{w}_i, i = 0..N-1$ denote the use of Walsh-vectors of length N_c chips;

as usual, the 'circle-multiplication' denotes component-wise multiplication of two vectors;

$\mathbf{s}$ is the scrambling sequence vector;

The received additive noise-affected composite multicode CDMA symbol at the output of the channel is:

$$\mathbf{z} = (\mathbf{x}_M \cdot \mathbf{W}) \circ \mathbf{s} + \mathbf{n}$$

with noise vector $\mathbf{n}$

At the receiver:

For each coded bit $x_0,\ldots,x_{N-1}$ that is transmitted within the composite multicode CDMA symbol $\mathbf{z}$ the demapper calculates the log-likelihood ratio (L-value) of the respective bit conditioned on $\mathbf{z}$. The absolute value of the L-value denotes the reliability of the bit decision. E.g. for bit x_k the demapper soft output is the L-value

$$L(x_k|\mathbf{z}) = L_a(x_k) + \ln \frac{\sum_{i=0}^{2^{N-1}-1} p\left(\mathbf{z}\middle| x_k = 1, x_{j,j=0..N-1,j\neq k} \equiv \mathrm{bin}(i)\right) \cdot \exp \sum_{\substack{j=0,j\neq k \\ \mathrm{btst}(i,\tilde{j})=1}}^{N-1} L_a(x_j)}{\sum_{i=0}^{2^{N-1}-1} p\left(\mathbf{z}\middle| x_k = 0, x_{j,j=0..N-1,j\neq k} \equiv \mathrm{bin}(i)\right) \cdot \exp \sum_{\substack{j=0,j\neq k \\ \mathrm{btst}(i,\tilde{j})=1}}^{N-1} L_a(x_j)}$$

where $x_{j,j=0..N-1,j\neq k} \equiv \mathrm{bin}(i)$ denotes the joint event of the variables $x_{j,j=0..N-1,j\neq k}$ taking on values 0, 1 according to the binary decomposition of i. E.g. for $N=4$, $k=1$, $i=5$ we have $x_3=1$, $x_2=0$ and $x_0=1$. The function $\mathrm{btst}(i,\tilde{j})$ takes on the value '1' if bit number $\tilde{j}$ is set in the binary decomposition of i, otherwise it is '0', with

$$\tilde{j} = \begin{cases} j & , j < k \\ j-1 & , j \geq k \end{cases}$$

For the real additive white Gaussian noise channel

$$\tilde{p}(\mathbf{z}|\hat{\mathbf{x}}) = \exp\left[\frac{1}{\sigma^2} \cdot \hat{\mathbf{x}}_M \cdot \mathbf{corr}\right]$$

whereby

$$\mathbf{corr} = (\mathbf{z} \circ \mathbf{s}) \cdot \mathbf{W}^T = \mathbf{x}_M \cdot \mathbf{W} \cdot \mathbf{W}^T + (\mathbf{n} \circ \mathbf{s}) \cdot \mathbf{W}^T = N_c \cdot \mathbf{x}_M + \tilde{\mathbf{n}}$$

denotes the vector of N correlation results at the receiver that are inputted to the demapper.

Note: $\hat{\mathbf{x}}_M = map(\hat{\mathbf{x}})$ is the hypothesised received mapped coded bit vector of the considered multicode CDMA symbol, and $\mathbf{x}_M = map(\mathbf{x})$ the actually transmitted one.

Further notations:

σ^2 is the power of the additive noise on the channel.

'ln' denotes the natural logarithm, 'exp' the exponential function.

The a priori L-value for, e.g., unmapped coded bit x_k is

$$L_a(x_k) = \ln\frac{P[x_k = 1]}{P[x_k = 0]}.$$

Note that the 'a priori' L-values of bits $\mathbf{x} = (x_0,...,x_{N-1})$ are provided by the SISO-decoder as inputs to the soft demapping device after the first decoding pass. For the very first decoding pass these values are set to zero.

After the subtraction of $L_a(x_k)$ (see fig. 3) only the so called 'extrinsic information' of the demapper is passed on to the deinterleaver and channel SISO-decoder.

The extension to complex signal processing (I-/Q-channel) is straightforward. The channelization codes do not need to be orthogonal.

Furthermore, the application in a multipath channel environment (typical for wireless communication channels) will be immediately apparent to one skilled in the art. A rake receiver is applied in order to compensate for multipath propagation. A rake receiver for coherent detection consists of a number of 'finger-correlators' (ideally, one finger per multipath component). The outputs of finger-correlators are then combined in a 'maximum ratio combiner'. The demapping is then performed after the maximum ratio combiner, working on the 'combined' correlation results.

The number of N parallel CDMA channels in the multicode CDMA signal, or mulituser CDMA signal respectively, does not have to be equal to the number of bits on which the mapping is performed. Moreover, the number of mapped bits could be both smaller or bigger than N. The appropriate changes in the mathematical description and figures would be immediately apparent to one skilled in the art.

The claims defining the invention are as follows:

1. A CDMA system comprising a transmitter and a receiver, the transmitter comprising a first encoder for encoding a signal, an interleaver for interleaving the encoded signal, and a second encoder for further encoding the interleaved signal,

the second encoder comprising a mapper means for mapping components of the interleaved signal to components of a desired mapped signal, whereby the mapped signal components are dependent on the components of the interleaved signal,

and spreading means for spreading each mapped component with a respective orthogonal spreading code,

and the receiver including despreading means for multiplying the received signal with said orthogonal spreading codes to provide components of the received signal,

a demapper means for reversing said mapping and for estimating the likely value of the received signal components,

a deinterleaver for deinterleaving the estimated component values, being coupled to a decoder means for decoding the encoding provided by said first encoder, and

a feedback path from the decoder to the demapper means including an interleaver, to enable the receiver to perform iterative decoding.

2. A transmitter for a CDMA system, comprising:

a first encoder for encoding a signal, an interleaver for interleaving the encoded signal, and a second encoder for further encoding the interleaved signal, the second encoder comprising a mapper means for mapping components of the interleaved signal to mapped components of a mapped signal, whereby the mapped signal components are dependent on the components of the interleaved signal, and spreading means for spreading each mapped component with an orthogonal spreading code.

3. A receiver for a CDMA system, for receiving a serially encoded signal having a first encoding followed by an interleaving and a second encoding with a mapping and orthogonal spreading codes, the receiver comprising:

despreading means for multiplying the received signal with said orthogonal spreading codes to provide components of the received signal,

a demapper means for reversing said mapping and for estimating the likely value of the received signal components,

AUSTRALIAN PATENT OFFICE

a deinterleaver for deinterleaving the estimated values of the received signal components,

a decoder for decoding the first encoding of the received signal, and

a feedback path from the decoder to the demapper means, including an interleaver, to enable the receiver to perform iterative decoding.

4. A system as claimed in claim 1 or a transmitter as claimed in claim 2, including a demultiplexer for splitting components of the interleaved signal onto parallel paths, the mapper means being operative to map said mapped components onto said parallel paths, and said spreading means including, in each parallel path, and means for spreading the mapped components of the with a respective orthogonal spreading code.

5. A system or transmitter as claimed in claim 4, including means for combining the spread signal components, and scrambling means for scrambling the combined signal prior to transmission.

6. A system as claimed in claim 1 or a transmitter as claimed in claim 2, wherein the first encoder provides an encoded signal in the form of digital bits, said interleaver is a bit interleaver, and the mapper means maps vector components of the interleaved signal to mapped vector components of the mapped signal.

7. A system as claimed in claim 1 or a receiver as claimed in claim 3, wherein the receiver includes descrambling means for descrambling a scrambled received signal.

8. A system as claimed in claim 1 or a receiver as claimed in claim 2, including despreading means, comprising a plurality of parallel paths, each containing multiplying means for multiplying the received signal with a respective orthogonal code.

9. A system or receiver as claimed in claim 8, wherein said demapper means has respective inputs coupled to said parallel paths to provide estimates of the likely values of the signal components, the estimated values being provided to a multiplexer means for transmission to said deinterleaver.

AUSTRALIAN PATENT OFFICE

10. A system as claimed in claim 1 or a receiver as claimed in claim 3, wherein said decoder comprises an APP calculator in order to provide a soft decision, and means for providing a hard decision therefrom.

11. A system as claimed in claim 1 or a transmitter as claimed in claim 2, wherein the mapper means performs a mapping of N coded bits (vector $\mathbf{x}$) to the mapped coded bit vector $\mathbf{x}_M = map(\mathbf{x}), \mathbf{x} = (x_0,\ldots,x_{N-1})$, $\mathbf{x}_M = (x_{M,0},\ldots,x_{M,N-1}); x_i, x_{M,i} \in \{-1,+1\}$

12. A transmitter as claimed in claim 1 or a receiver according to claim 3, wherein the demapper means provides estimated values L of the received components as follows:

$$L(x_k \mid \mathbf{z}) = L_a(x_k) + \ln \frac{\sum_{i=0}^{2^{N-1}-1} p\left(\mathbf{z} \mid x_{j,j=0..N-1,j\neq k} \equiv \mathrm{bin}(i)\right) \cdot \exp \sum_{\substack{j=0,j\neq k \\ \mathrm{bist}(i,j)=1}}^{N-1} L_a(x_j)}{\sum_{i=0}^{2^{N-1}-1} p\left(\mathbf{z} \mid x_k = 0, x_{j,j=0..N-1,j\neq k} \equiv \mathrm{bin}(i) \cdot \exp \sum_{\substack{j=0,j\neq k \\ \mathrm{bist}(i,j)=1}}^{N-1} L_a(x_j)\right.}$$

13. A method of transmitting a CDMA signal, comprising:

performing a first encoding of a signal, interleaving the encoded signal, and performing a second encoding of the interleaved signal,

the second encoding including a mapping of components of the interleaved signal to mapped components of a mapped signal, whereby the mapped signal components are dependent on the components of the interleaved signal, and

spreading each mapped component with an orthogonal spreading code.

14. A method of receiving a CDMA signal, comprising:

receiving a serially encoded signal having a first encoding followed by an interleaving and a second encoding with a mapping and orthogonal spreading codes,

performing a despreading of the received signal by multiplying the received signal with said orthogonal spreading codes to provide components of the received signal,

AUSTRALIAN PATENT OFFICE

demapping the received signal, including reversing and mapping and estimating the likely value of the received signal components,

deinterleaving the estimated values of the received signal components,

decoding said first encoding of the received signal, and

feeding back the decoded values as a priori knowledge to said demapping, to enable iterative decoding.

15. A CDMA system substantially as described herein with reference to Fig. 3.

16. A transmitter for a CDMA system, said transmitter being substantially as described herein with reference to Fig. 3.

17. A receiver for a CDMA system, said receiver being substantially as described herein with reference to Fig. 3.

DATED this Twenty Second Day of September, 2000

Lucent Technologies Inc.

Patent Attorneys for the Applicant

SPRUSON & FERGUSON

AUSTRALIAN PATENT OFFICE

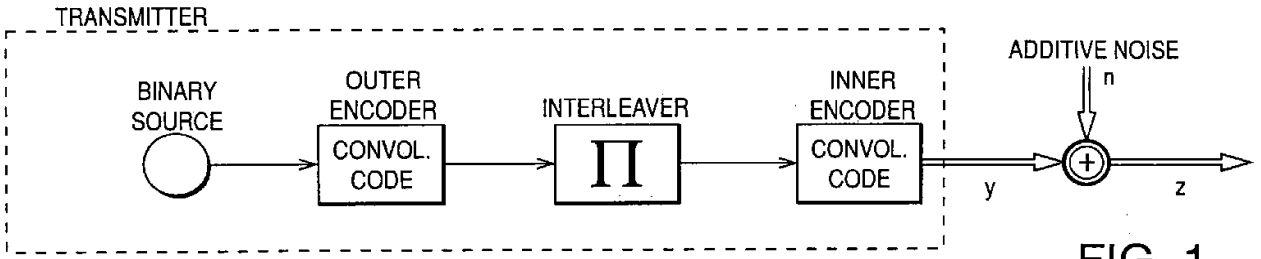
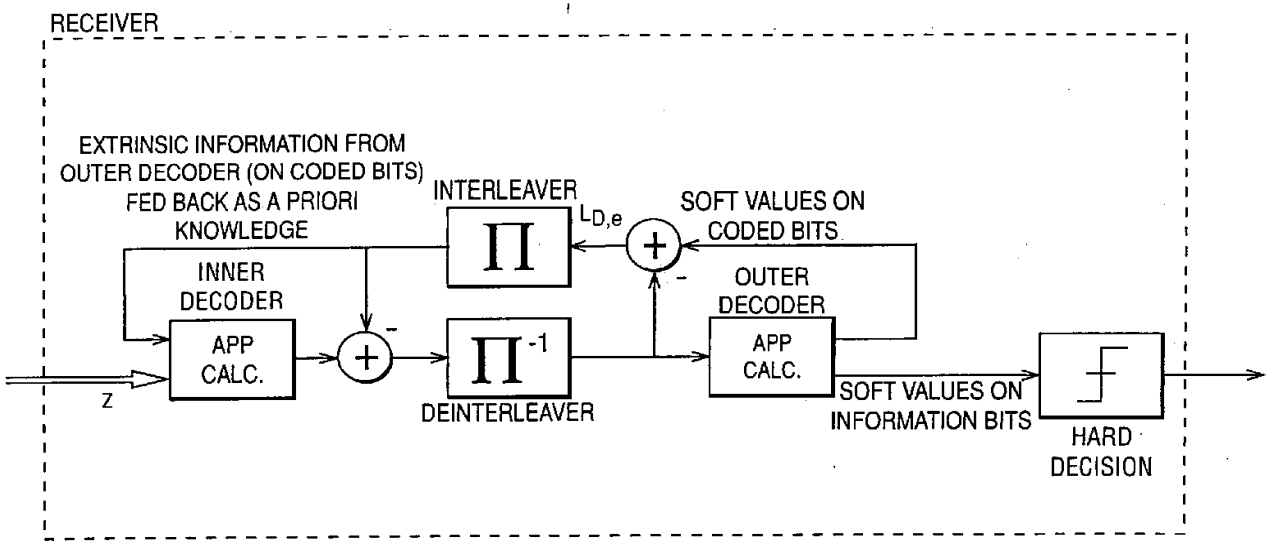

TRANSMITTER
BINARY SOURCE
OUTER ENCODER
CONVOL. CODE
INTERLEAVER
Π
INNER ENCODER
CONVOL. CODE
ADDITIVE NOISE
n
y
z

FIG. 1


RECEIVER
EXTRINSIC INFORMATION FROM OUTER DECODER (ON CODED BITS) FED BACK AS A PRIORI KNOWLEDGE
INTERLEAVER
Π
$L_{D,e}$
SOFT VALUES ON CODED BITS
INNER DECODER
APP CALC.
z
Π -1
DEINTERLEAVER
OUTER DECODER
APP CALC.
SOFT VALUES ON INFORMATION BITS
HARD DECISION

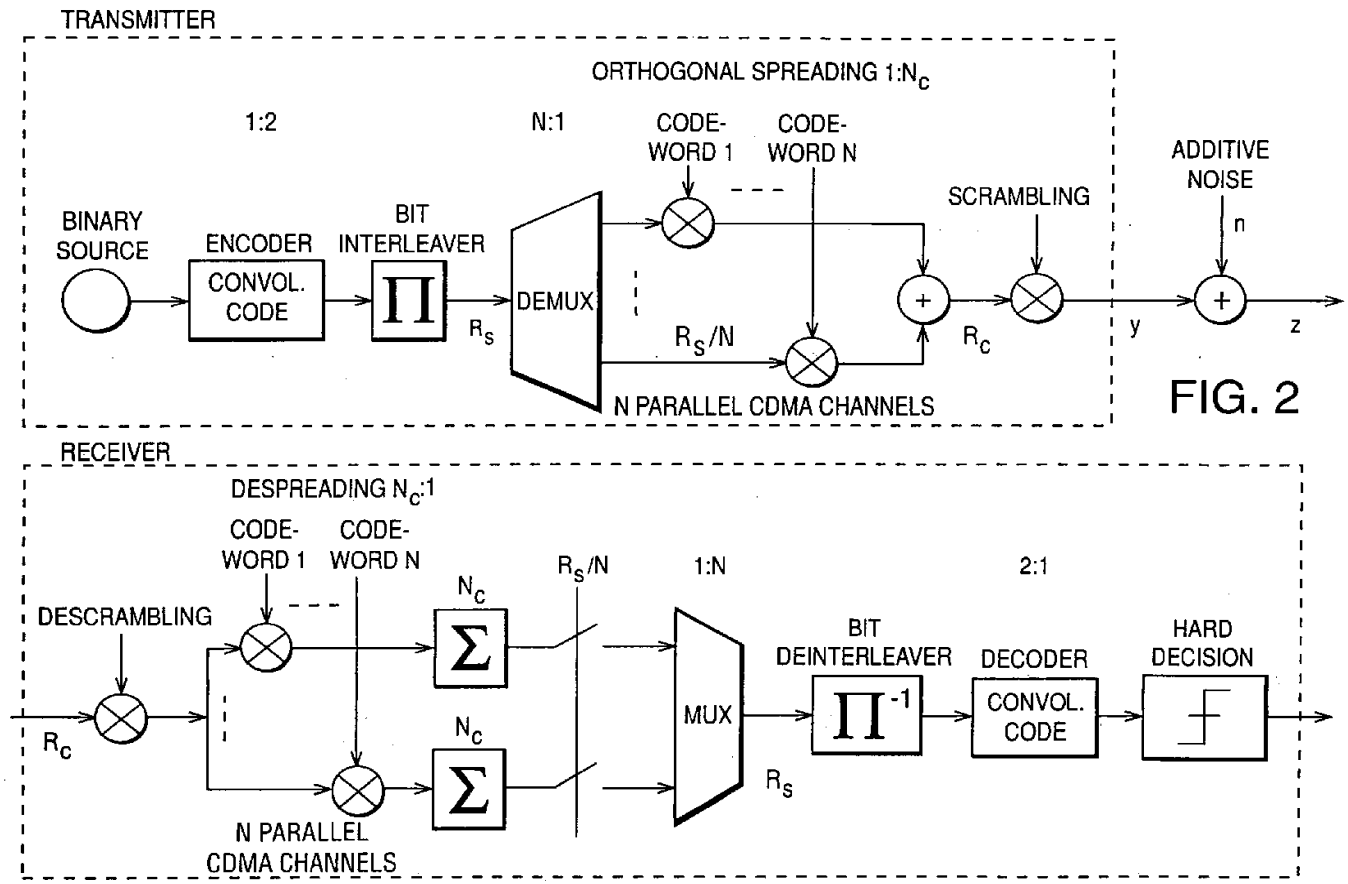

TRANSMITTER
ORTHOGONAL SPREADING 1:N_c
1:2
N:1
CODE-WORD 1
CODE-WORD N
SCRAMBLING
ADDITIVE NOISE
BINARY SOURCE
ENCODER
CONVOL. CODE
BIT INTERLEAVER
DEMUX
R_s
R_s/N
R_c
y
n
z
N PARALLEL CDMA CHANNELS
RECEIVER
DESPREADING N_c:1
CODE-WORD 1
CODE-WORD N
R_s/N
1:N
2:1
DESCRAMBLING
N_c
N_c
BIT DEINTERLEAVER
DECODER
HARD DECISION
MUX
CONVOL. CODE
R_c
R_s
N PARALLEL CDMA CHANNELS

FIG. 2

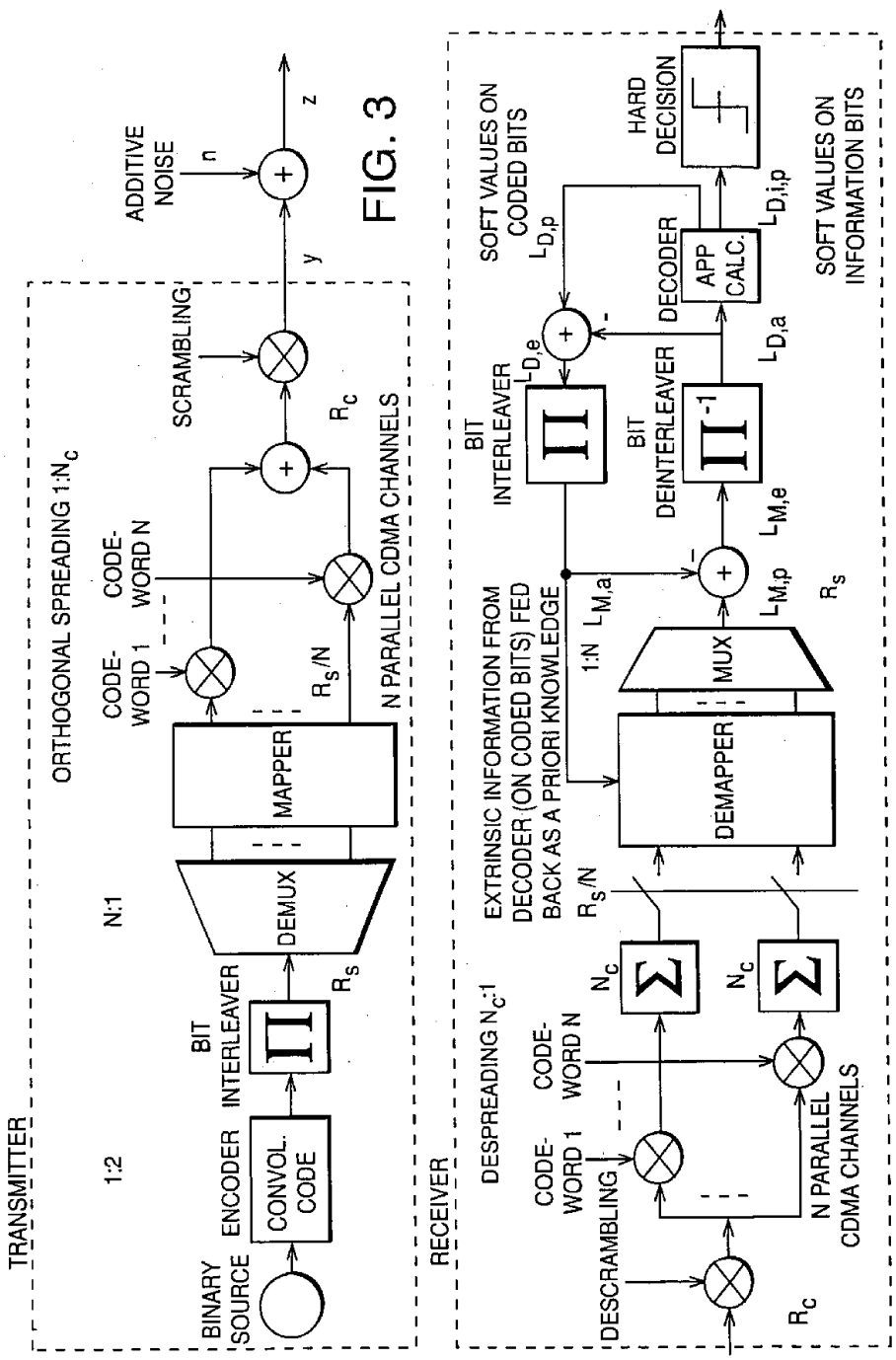

TRANSMITTER
BINARY SOURCE
ENCODER
CONVOL. CODE
1:2
BIT INTERLEAVER
DEMUX
N:1
R_s
R_s/N
ORTHOGONAL SPREADING 1:N_c
CODE-WORD 1
CODE-WORD N
MAPPER
N PARALLEL CDMA CHANNELS
R_c
SCRAMBLING
ADDITIVE NOISE
n
z
y
RECEIVER
DESCRAMBLING
CODE-WORD 1
CODE-WORD N
DESPREADING N_c:1
N_c
N PARALLEL CDMA CHANNELS
R_c
R_s/N
EXTRINSIC INFORMATION FROM DECODER (ON CODED BITS) FED BACK AS A PRIORI KNOWLEDGE
1:N
$L_{M,a}$
DEMAPPER
MUX
$L_{M,p}$
$L_{M,e}$
R_s
BIT INTERLEAVER
BIT DEINTERLEAVER
$L_{D,e}$
$L_{D,a}$
DECODER
APP CALC.
$L_{D,i,p}$
SOFT VALUES ON CODED BITS
$L_{D,p}$
HARD DECISION
SOFT VALUES ON INFORMATION BITS

FIG. 3