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Cancellation of pilot and unwanted traffic signals in a CDMA system

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(71) Applicant(s)  
Interdigital Technology Corporation

(72) Inventor(s)  
Fatih M. Ozluturk

(74) Agent/Attorney  
WATERMARK PATENT and TRADEMARK ATTORNEYS, Locked Bag 5, HAWTHORN  
VIC 3122

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<p>(21) International Application Number: PCT/US99/01883 (22) International Filing Date: 27 January 1999 (27.01.99) (30) Priority Data: 09/175,174 20 October 1998 (20.10.98) US (71) Applicant: INTERDIGITAL TECHNOLOGY CORPORATION [US/US]; Suite 525, 300 Delaware Avenue, Wilmington, DE 19801 (US). (72) Inventor: OZLUTURK, Fatih, M.; 70 Willowdale Avenue, Port Washington, NY 11050 (US). (74) Agents: VOLPE, Anthony, S. et al.; Volpe and Koenig, P.C., 400 One Penn Center, 1617 John F. Kennedy Boulevard, Philadelphia, PA 19103 (US).</p>	<p>(81) Designated States: AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, DE, DK, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, UA, UG, UZ, VN, YU, ZW, ARIPO patent (GH, GM, KE, LS, MW, SD, SZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).</p> <p>Published With international search report.</p>	
<p>(54) Title: CANCELLATION OF PILOT AND UNWANTED TRAFFIC SIGNALS IN A CDMA SYSTEM</p>		
<p>The diagram shows a QPSK constellation in the complex plane with the horizontal axis labeled 'I (Real)' and the vertical axis labeled 'Q (Imaginary)'. The four constellation points are marked with 'X' and labeled: X<sub>1,1</sub> at (1,1), X<sub>-1,1</sub> at (-1,1), X<sub>1,-1</sub> at (1,-1), and X<sub>-1,-1</sub> at (-1,-1). A received symbol P<sub>0</sub> is shown as a point in the second quadrant. Four dashed lines represent distances d<sub>1</sub>, d<sub>2</sub>, d<sub>3</sub>, and d<sub>4</sub> from P<sub>0</sub> to the constellation points X<sub>1,1</sub>, X<sub>-1,1</sub>, X<sub>1,-1</sub>, and X<sub>-1,-1</sub> respectively. The origin is marked with '0'.</p>		
<p>(57) Abstract</p> <p>A global pilot (61) and unwanted traffic (115i) signal canceler for a spread spectrum communication system receiver that reduces their contributive noise effects (149). The present invention effectively cancels the global pilot and unwanted, active traffic signals prior to decoding a desired traffic signal at the receiver. The system and method decreases the bit error rate (BER) yielding an increased signal-to-noise ratio.</p>		

## CANCELLATION OF PILOT AND UNWANTED TRAFFIC SIGNALS IN A CDMA SYSTEM

**BACKGROUND OF THE INVENTION****Field of the Invention**

5 The present invention relates generally to digital communications. More specifically, the invention relates to a system and method which cancels the global pilot signal and unwanted traffic signals from a received code division multiple access signal thereby removing them as interferers prior to decoding.

**10 Description of the Prior Art**

Advanced communication technology today makes use of a communication technique in which data is transmitted with a broadened band by modulating the data to be transmitted with a pseudo-noise (pn) signal. The technology is known as digital spread spectrum or code divisional multiple access (CDMA). By transmitting a signal with a bandwidth much greater than the signal bandwidth, CDMA can transmit data without being affected by signal distortion or an interfering frequency in the transmission path.

20 Shown in **Figure 1** is a simplified, single channel CDMA communication system. A data signal with a given bandwidth is mixed with a spreading code generated by a pn sequence generator producing a digital spread spectrum signal. The signal which carries data for a specific channel is known as a traffic signal. Upon reception, the data is reproduced after correlation with the same pn sequence used to transmit the data. Every other signal within the transmission bandwidth appears as noise to the signal being despread.

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For timing synchronization with a receiver, an unmodulated traffic signal known as a pilot signal is required for every transmitter. The pilot signal allows respective receivers to synchronize with a given transmitter, allowing despreading of a traffic signal at the receiver.

5 In a typical communication system, a base station communicates with a plurality of individual subscribers fixed or mobile. The base station which transmits many signals, transmits a global pilot signal common to the plurality of users serviced by that particular base station at a higher power level. The global pilot is used for the initial acquisition of an individual user and for the user to  
10 obtain signal-estimates for coherent reception and for the combining of multipath components during reception. Similarly, in a reverse direction, each subscriber transmits a unique assigned pilot for communicating with the base station.

Only by having a matching pn sequence can a signal be decoded, however, all signals act as noise and interference. The global pilot and traffic  
15 signals are noise to a traffic signal being despread. If the global pilot and all unwanted traffic signals could be removed prior to despreading a desired signal, much of the overall noise would be reduced, decreasing the bit error rate and in turn, improve the signal-to-noise ratio (SNR) of the despread signal.

Some attempts have been made to subtract the pilot signal from the  
20 received signal based on the relative strength of the pilot signal at the receiver. U.S. Patent No. 5,224,122 to Bracket discloses a spread-spectrum noise canceller which cancels a portion of spread-spectrum noise signal in the received signal by generating an estimated signal by spreading the known signal. Subsequently, the known signal is processed out of the received spread-  
25 spectrum signal by subtracting the estimated signal from the demodulated form of the received spread-spectrum signal. Where the estimated signals is generated based on the amplitude and the phase information of the known signals received from a base station in a primary serving cell, and the amplitudes information from the noise of multipath signal and the noise signal from a secondary serving cell.  
30 WO 98/43362 to Yellin et al. discloses a CDMA noise canceller by detecting at least one noisy user signal from a spread-spectrum signal and removing the noise of pilot signal and its interference effect the particular user signal. However, the strength value is not an accurate characteristic for calculating

interference due to the plurality of received signals with different time delays caused by reflections due to terrain. Multipath propagation makes power level estimates unreliable.

There is need to improve overall system performance by removing multiple  
5 noise contributors from a signal prior to decoding.

#### **SUMMARY OF THE INVENTION**

The present invention aims to reduce the contributive noise effects of the global pilot signal and unwanted traffic signals transmitted in a spread spectrum communication system. The present invention aims to cancel the global pilot and  
15 unwanted traffic signal(s) from a desired traffic signal at a receiver prior to decoding. The resulting signal has an increased signal-to-noise ratio.

Accordingly, it is an object of the present invention to provide a code division multiple access communication system receiver which reduces the contributive noise effects from the pilot and active, unwanted traffic signals.

15 It is a preferred object of the present invention to improve the desired traffic signal SNR by eliminating the noise effects of the global pilot and active traffic signals.

Other objects and advantages of the system and method will become apparent to those skilled in the art of advanced telecommunications after reading  
20 the detailed description of the preferred embodiment.

With the aforementioned in mind, the present invention in one aspect provides a cancellation system for removing selected signals from a traffic signal prior to decoding in a receiver that receives communication signals from a transmitter over a CDMA air interface, the system including:

- 25 a system input for receiving the communication signals;
- said system input inputted as input to a traffic signal cancellation system having an output equal to the desired traffic signal minus the unwanted traffic signals;
- said system input also inputted as input to a pilot signal cancellation  
30 system, the system processing the input to remove a global pilot signal and having an output equal to the desired traffic signal minus the global pilot signal;
- and

whereby the output of the pilot signal cancellation system is subtracted from the output of the traffic signal cancellation system to provide the cancellation system output.

A further aspect of the present invention provides a global pilot signal  
5 cancellation system for use in a receiver that receives communication signals from a transmitter over a CDMA air interface that removes the global pilot signal from a desired traffic signal prior to decoding, the system including:

an input for receiving the communication signals and a system output;

said input coupled to a global pilot despreader and a desired traffic signal  
10 despreader each having a summed output;

a desired traffic signal and global pilot cross-correlation means;

said global pilot despreader output coupled to a pilot strength determining means, said determining means having an output;

said pilot strength determining means output multiplied with said cross-  
15 correlation means output; and

said multiplied product subtracted from a summed output of said desired traffic signal despreader output outputting the desired traffic signal free from the global pilot signal.

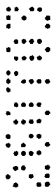


According to a still further aspect of the present invention there is provided  
20 a traffic signal cancellation system for use in a receiver that receives communication signals from transmitter over a CDMA air interface that removes at least one unwanted traffic signal from a desired traffic signal prior to decoding, the system including:

an input for receiving the communication signals and a system output;

said input coupled to a desired traffic signal despreader having a first  
25 summed output;

an at least one unwanted traffic signal canceler including:



an unwanted traffic signal despreader having an input coupled to  
said first summed output and a second summed output;

3b

the unwanted traffic signal despreaders including an unwanted traffic signal code generator and a mixer for mixing an output of the generator with the input to produce an unwanted traffic signal despreaders output;

said unwanted traffic signal despreaders summed output coupled to a hard  
5 decision processor having a phase output and a data output;

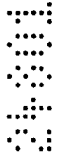
said hard decision processor phase output coupled to a low pass filter,  
said low pass filter having an output;

said low pass filter output coupled to an input of a processor that filters the  
product of the unwanted traffic signal to desired traffic signal cross-correlation  
10 outputting the unwanted traffic signal strength;

said processor output multiplied with said hard decision data output with a  
multiplier having an output delivered to an adjustable amplifier;

an unwanted traffic code generator output coupled to an input of a complex  
conjugate processor having an output;

15 said complex conjugate output mixed with a complex conjugate of the  
desired traffic signal code by a mixer having an output;



said mixer output coupled to an input of a second sum and dump  
processor having an output;

said second sum and dump processor coupled to an input of an amplifier  
20 having an adjustable gain controlled by said multiplier output; and

said output of said amplifier is coupled to an adder which subtracts the  
output of each variable amplifier from the output of the desired traffic signal  
despreaders to get the output of the traffic cancellation system.



**BRIEF DESCRIPTION OF THE DRAWINGS**

**Figure 1** is a simplified block diagram of a prior art, CDMA communication system.

**Figure 2A** is a detailed block diagram of a B-CDMA™ communication system.

**Figure 2B** is a detailed system diagram of a complex number multiplier.

**Figure 3A** is a plot of an in-phase bit stream.

**Figure 3B** is a plot of a quadrature bit stream.

**Figure 3C** is a plot of a pseudo-noise (pn) bit sequence.

**Figure 4** is a block diagram of a global pilot signal cancellation system according to the present invention.

**Figure 5** is a block diagram of an unwanted traffic signal(s) cancellation system according to the present invention.

**Figure 6** is a diagram of a received symbol  $p$ , on the QPSK constellation showing a hard decision.

**Figure 7** is a block diagram of a combined pilot and unwanted traffic signal cancellation system according to the present invention.

**DESCRIPTION OF THE PREFERRED EMBODIMENTS**

The preferred embodiments will be described with reference to the drawing figures where like numerals represent like elements throughout.

A B-CDMA™ communication system 17 as shown in **Figure 2** includes a transmitter 19 and a receiver 21, which may reside in either a base station or a mobile user receiver. The



-5-

transmitter 19 includes a signal processor 23 which encodes voice and nonvoice signals 25 into data at various bit rates.

By way of background, two steps are involved in the generation of a transmitted signal in a multiple access environment. First, the input data which can be considered a bi-phase modulated signal is encoded using forward error-correcting coding (FEC) 27. One signal is designated the in-phase channel  $I$  33x. The other signal is designated the quadrature channel  $Q$  33y. Bi-phase modulated  $I$  and  $Q$  signals are usually referred to as quadrature phase shift keying (QPSK).

In the second step, the two bi-phase modulated data or symbols 33x, 33y are spread with a complex, pseudo-noise (pn) sequence 35I, 35Q using a complex number multiplier 39. The operation of a complex number multiplier 39 is shown in Figure 2B and is well understood in the art. The spreading operation can be represented as:

$$\begin{aligned} (x+jy) \times (I+jQ) &= (xI-yQ) + j(xQ+yI) && \text{Equation (1)} \\ &= a+jb. \end{aligned}$$

A complex number is in the form  $a+jb$ , where  $a$  and  $b$  are real numbers and  $j^2=-1$ . Referring back to Figure 2a, the resulting  $I$  37a and  $Q$  37b spread signals are combined 45a, 45b with other spread signals (channels) having different spreading codes, multiplied (mixed) with a carrier signal 43,

and transmitted 47. The transmission 47 may contain a plurality of individual signals.

The receiver 21 includes a demodulator 49a, 49b which mixes down the transmitted broadband signal 47 with the transmitting carrier 43 into an intermediate carrier frequency 51a, 51b. A second down conversion reduces the signal to baseband. The QPSK signal 55a, 55b is then filtered 53 and mixed 56 with the locally generated complex pn sequence 35I, 35Q which matches the conjugate of the transmitted complex code. Only the original signals which were spread by the same code will be despread. All other signals will appear as noise to the receiver 21. The data 57x, 57y is coupled to a signal processor 59 where FEC decoding is performed on the convolutionally encoded data.

As shown in Figures 3A and 3B, a QPSK symbol consists of one bit each from both the in-phase (*I*) and quadrature (*Q*) signals. The bits may represent a quantized version of an analog sample or digital data. It can be seen that symbol duration  $t_s$  is equal to bit duration.

The transmitted symbols are spread by multiplying the QPSK symbol stream by the complex pn sequence. Both the *I* and *Q* pn sequences are comprised of a bit stream generated at a much higher frequency, typically 100 to 200 times the symbol rate. One such pn sequence is shown in Figure 3C. The complex pn sequence is mixed with the symbol bit stream producing the digital spread signal (as previously discussed).

-7-

The components of the spread signal are known as chips having a much smaller duration  $t_c$ .

When the signal is received and demodulated, the baseband signal is at the chip level. When the  $I$  and  $Q$  components of the signal are despread using the conjugate of the pn sequence used during spreading, the signal returns to the symbol level.

The embodiments of the present invention are shown in Figures 4, 5 and 7. The global pilot signal cancellation system 61 embodiment is shown in Figure 4. A received signal  $r$  is expressed as:

$$r = \alpha c_p + \beta c_t + n \quad \text{Equation (2)}$$

where the received signal  $r$  is a complex number and is comprised of the pilot strength  $\alpha$  multiplied with the pilot code  $c_p$ , summed with the traffic strength  $\beta$  multiplied with the traffic code  $c_t$ , summed with random noise  $n$ . The noise  $n$  includes all received noise and interference including all other traffic signals. To cancel the global pilot signal from the received signal  $r$ , the system 61 must derive the signal strength of the pilot code  $\alpha$  where:

$$\alpha \neq \beta \quad \text{Equation (3)}$$

since the global pilot is transmitted at a higher power level than a traffic signal.

-8-

When the received signal  $r$  is summed over time, Equation (2) becomes:

$$\Sigma r = \alpha \Sigma c_p + \beta \Sigma c_i + \Sigma n. \quad \text{Equation (4)}$$

Referring to Figure 4, the received baseband signal  $r$  is input 63 into the pilot signal cancellation system 61 and into a pilot despreader 65 which despreads the pilot signal from the received signal  $r$ . First mixer 67 despreads the received signal  $r$  by multiplying with the complex conjugate  $c_p^*$  69 of the pilot pn code used during spreading yielding:

$$\Sigma r c_p^* = \alpha \Sigma c_p c_p^* + \beta \Sigma c_i c_p^* + \Sigma n c_p^*. \quad \text{Equation (5)}$$

A complex conjugate is one of a pair of complex numbers with identical real parts and with imaginary parts differing only in sign.

The despread pilot signal 71 is coupled to a first sum and dump processor 73 where it is summed over time. The first sum and dump 73 output  $O_{adi}$  is:

$$O_{adi} = \alpha L + \beta \Sigma c_i c_p^* + \Sigma n c_p^* \quad \text{Equation (6)}$$

where  $L$  is the product of the pilot spreading code  $c_p$  and the complex conjugate of the pilot spreading code  $c_p^*$  summed over  $L$  chips.

The sum and dump 73 output  $O_{sd1}$  is coupled to a low pass filter 75. The low pass filter 75 determines the mean value for each signal component. The mean value for pilot-traffic cross-correlation is zero and so is the mean value of the noise  $n$ . Therefore, after filtering 75, the second and third terms in Equation (6) become zero. The low pass filter 75 output  $O_{lpf}$  over time is:

Equation (7)

$$O_{lpf} = \alpha L.$$

The low pass filter 75 output  $O_{lpf}$  is coupled to a processing means 77 to derive the pilot code strength  $\alpha$ . The processing means 77 calculates  $\alpha$  by dividing the low pass filter 79 output  $O_{lpf}$  by  $L$ . Thus, the processing means 77 output  $O_{pm}$  is:

Equation (8)

$$O_{pm} = \alpha.$$

The pilot spreading code  $c_p^*$  complex conjugate generator 69 is coupled to a complex conjugate processor 79 yielding the pilot spreading code  $c_p$ . The pilot spreading code  $c_p$  is input to a second mixer 81 and mixed with the output of a traffic spreading code  $c_t^*$  complex conjugate generator 83. The resulting product from the second mixer 81 output is coupled to a second sum and dump processor 85. The output  $O_{sd2}$  of the

second sum and dump processor 85 is  $\sum c_p c_i'$  and is combined with  $\alpha$  at a third mixer 87. The third mixer 87 output 89 is  $\alpha \sum c_p c_i'$ .

The received signal  $r$  is also despread by traffic despreader 91. The traffic despreader 91 despreads the received signal  $r$  by mixing the received signal  $r$  with the traffic code  $c_i^*$  complex conjugate generator 83 using a fourth mixer 93 yielding:

$$\sum r c_i^* = \alpha \sum c_p c_i^* + \beta \sum c_p c_i^* + \sum n c_i^* \quad \text{Equation (9)}$$

The traffic despreader 91 output 95 is coupled to a third sum and dump 97. The third sum and dump 97 output  $O_{sd3}$  over time is:

$$O_{sd3} = \sum r c_i^* = \beta L + \alpha \sum c_p c_i^* + \sum n c_i^* \quad \text{Equation (10)}$$

where  $L$  is the product of the traffic spreading code  $c_i$  and the complex conjugate of the traffic spreading code  $c_i^*$  summed over  $L$  chips.

The third sum and dump 97 output  $O_{sd3}$  is coupled to an adder 99 which subtracts the third mixer 87 output 89. The adder 99 output  $O_{add}$  is:

$$O_{add} = \beta L + \alpha \sum c_p c_i^* + \sum n c_i^* - \alpha \sum c_p c_i^* \quad \text{Equation (11)}$$

-11-

Thus, the pilot canceler 61 output  $O_{add}$  is equal to the received signal  $r$  minus the pilot signal simplified below:

$$O_{add} = \beta L + \sum n c_i^* \quad \text{Equation (12)}$$

The invention uses a similar approach to cancel unwanted traffic signal(s) from a desired traffic signal. While traffic signals are interference to other traffic signals just as the global pilot signal is, unwanted traffic signal cancellation differs from global pilot signal cancellation since a traffic signal is modulated by the data and is therefore dynamic in nature. A global pilot signal has a constant phase, whereas a traffic signal constantly changes phase due to data modulation.

The traffic signal canceler system 101 embodiment is shown in **Figure 5**. As above, a received signal  $r$  is input 103 to the system:

$$r = \psi d c_d + \beta c_i + n \quad \text{Equation (13)}$$

where the received signal  $r$  is a complex number and is comprised of the traffic code signal strength  $\psi$  multiplied with the traffic signal data  $d$  and the traffic code  $c_d$  for the unwanted traffic signal to be canceled, summed with the desired traffic code strength  $\beta$  multiplied with the desired traffic code  $c_i$ , summed with noise  $n$ . The noise  $n$  includes all received noise and interference including all other traffic

-12-

signals and the global pilot signal. To cancel the unwanted traffic signal(s) from the received signal  $r$ , the system 101 must derive the signal strength of the unwanted traffic code  $\psi$  to be subtracted and estimate the data  $d$ , where:

$$5 \quad \psi \neq d \neq \beta. \quad \text{Equation (14)}$$

When the received signal  $r$  is summed over time, Equation 13 can be expressed as:

$$\Sigma r = \psi d \Sigma c_i + \beta \Sigma c_i + \Sigma n. \quad \text{Equation (15)}$$

Referring to Figure 5, the received baseband signal  $r$  is input 103 into the desired traffic signal despreader 91 which despreads the desired traffic signal from the received signal  $r$ . Desired traffic signal mixer 93 mixes the received signal  $r$  with the complex conjugate  $c_i^*$  of the desired traffic pn code used during spreading. The despread traffic signal is coupled to a sum and dump processor 97 and summed over time. The sum and dump 97 output  $O_{adb}$  is:

$$O_{adb} = \Sigma r c_i^* = \beta L + \psi d \Sigma c_i c_i^* + \Sigma n c_i^*. \quad \text{Equation (16)}$$

The traffic signal canceler system 101 shown in Figure 5 includes  $n$  unwanted traffic signal cancelers 115<sub>1</sub>-115<sub>n</sub>. An



exemplary embodiment includes 10 (where  $n=10$ ) unwanted traffic signal cancelers 115<sub>1</sub>-115<sub>10</sub>.

Each unwanted traffic signal canceler 115<sub>1</sub>-115<sub>n</sub> comprises: an unwanted traffic signal despreader 139<sub>1</sub>-139<sub>n</sub> that includes a first mixer 117<sub>1</sub>-117<sub>n</sub> and an unwanted traffic signal code generator 119<sub>1</sub>-119<sub>n</sub>; second 133<sub>1</sub>-133<sub>n</sub> mixer, first 121<sub>1</sub>-121<sub>n</sub> and second 123<sub>1</sub>-123<sub>n</sub> sum and dump processors, a hard decision processor 125<sub>1</sub>-125<sub>n</sub>, a low pass filter 127<sub>1</sub>-127<sub>n</sub>, a processing means 129<sub>1</sub>-129<sub>n</sub>, third mixer 131<sub>1</sub>-131<sub>n</sub>, a conjugate processor 135<sub>1</sub>-135<sub>n</sub>, an adjustable amplifier 137<sub>1</sub>-137<sub>n</sub>, and a desired traffic signal code generator 83.

As above, the received signal  $r$  is input 103 into each unwanted traffic canceler 115<sub>1</sub>-115<sub>n</sub>. The unwanted traffic signal despreader 139<sub>1</sub>-139<sub>n</sub> is coupled to the input 103 where the received signal  $r$  is mixed 117<sub>1</sub>-117<sub>n</sub> with the complex conjugate  $c_{dl}^* \cdot c_{dn}^*$  of the traffic pn sequence for each respective unwanted signal. The despread 139<sub>1</sub>-139<sub>n</sub> traffic signal is coupled to a first sum and dump processor 121<sub>1</sub>-121<sub>n</sub> where it is summed over time. The first sum and dump 121<sub>1</sub>-121<sub>n</sub> output  $O_{adln}$  is:

$$O_{adln} = \sum r c_{dn}^* = \psi dL + \beta \sum c_{fdn}^* + \sum n c_{dn}^* \quad \text{Equation (17)}$$

where  $L$  is the product of the unwanted traffic signal spreading code  $c_{dn}$  and  $c_{dn}^*$  is the complex conjugate of the unwanted traffic signal spreading code.

-14-

The first sum and dump 121<sub>1</sub>-121<sub>n</sub> output  $O_{ddn}$  is coupled to the hard decision processor 125<sub>1</sub>-125<sub>n</sub>. The hard decision processor 125<sub>1</sub>-125<sub>n</sub> determines the phase shift  $\phi$  in the data due to modulation. The hard decision processor 125<sub>1</sub>-125<sub>n</sub> also  
5 determines the QPSK constellation position  $d$  that is closest to the despread symbol value.

As shown in Figure 6, the hard decision processor 125<sub>1</sub>-125<sub>n</sub> compares a received symbol  $p_o$  of a signal to the four QPSK constellation points  $x_{1,1}$ ,  $x_{-1,1}$ ,  $x_{1,-1}$ ,  $x_{-1,-1}$ . It is necessary to  
10 examine each received symbol  $p_o$  due to corruption during transmission 47 by noise and distortion, whether multipath or radio frequency. The hard decision processor computes the four distances  $d_1$ ,  $d_2$ ,  $d_3$ ,  $d_4$  to each quadrant from the received symbol  $p_o$  and chooses the shortest distance  $d_2$  and assigns that  
15 symbol  $d$  location  $x_{-1,1}$ . The hard decision processor also derotates (rotates back) the original signal coordinate  $p_o$  by a phase amount  $\phi$  that is equal to the phase corresponding to the selected symbol location  $x_{-1,1}$ . The original symbol coordinate  $p_o$  is discarded.

20 The hard decision processor 125<sub>1</sub>-125<sub>n</sub> phase output  $\phi$  is coupled to a low pass filter 127<sub>1</sub>-127<sub>n</sub>. Over time, the low pass filter 127<sub>1</sub>-127<sub>n</sub> determines the mean value for each signal component. The mean value of the traffic-to-traffic cross-correlation and also the mean value of the noise  $n$  are

-15-

zero. Therefore, the low pass filter 127<sub>1</sub>-127<sub>n</sub> output  $O_{lpf}$  over time is:

$$O_{lpf} = \psi L. \quad \text{Equation (18)}$$

The low pass filter 127<sub>1</sub>-127<sub>n</sub> output  $O_{lpf}$  is coupled to  
 5 the processing means 129<sub>1</sub>-129<sub>n</sub> to derive the unwanted traffic  
 signal code strength  $\psi$ . The processing means 129<sub>1</sub>-129<sub>n</sub>  
 estimates  $\phi$  by dividing the filter 127<sub>1</sub>-127<sub>n</sub> output  $O_{lpf}$  by  $L$ .

The other hard decision processor 125<sub>1</sub>-125<sub>n</sub> output is  
 data  $d$ . This is the data point  $d$  corresponding to the  
 10 smallest of the distances  $d_1, d_2, d_3$ , or  $d_4$  as shown in Figure 6.  
 Third mixer 131<sub>1</sub>-131<sub>n</sub> mixes the unwanted traffic signal  
 strength  $\psi$  with each data value  $d$ .

The unwanted traffic signal spreading code complex  
 conjugate generator  $c_{di}^* - c_{di}^*$  is coupled to the complex  
 15 conjugate processor 135<sub>1</sub>-135<sub>n</sub> yielding the unwanted traffic  
 signal spreading code  $c_{di} - c_{di}$  and is input to the second mixer  
 133<sub>1</sub>-133<sub>n</sub> and mixed with the output of desired traffic signal  
 spreading code complex conjugate generator  $c_i^*$ . The product  
 is coupled to the second sum and dump processor 123<sub>1</sub>-123<sub>n</sub>.  
 20 The second sum and dump processor 123<sub>1</sub>-123<sub>n</sub> output  $O_{sd2}$  is  
 $\sum c d_i c_i^*$  and is coupled to variable amplifier 137<sub>1</sub>-137<sub>n</sub>. Variable  
 amplifier 137<sub>1</sub>-137<sub>n</sub> amplifies the second sum and dump

-16-

processor 123<sub>1</sub>-123<sub>n</sub> output  $O_{add}$  in accordance with the third mixer 131<sub>1</sub>-131<sub>n</sub> output which is the determined gain.

The variable amplifier 137<sub>1</sub>-137<sub>n</sub> output 141<sub>1</sub>-141<sub>n</sub> is coupled to an adder 143 which subtracts the output from each variable amplifier 137<sub>1</sub>-137<sub>n</sub> from the output of the desired traffic signal despreaders 105. The output  $O$  is:

$$O = \beta L + \psi d \Sigma c_i^* + \Sigma n c_i^* - \psi d \Sigma c_i^* \quad \text{Equation (19)}$$

The adder 143 output  $O$  (also the unwanted traffic canceler system 101 output) is equal to the received signal  $r$  minus the unwanted traffic signals simplified below:

$$O = \beta L + \Sigma n c_i^* \quad \text{Equation (20)}$$

where the noise  $n$  varies depending on the amount of traffic signals subtracted from the received signal.

Another embodiment 145 cancelling the global pilot signal and unwanted traffic signals is shown in Figure 7. As previously discussed, the unwanted traffic cancellation system 101 includes the desired traffic signal despreaders 91 and a plurality of unwanted traffic signal cancelers 115<sub>1</sub>-115<sub>n</sub>. The traffic cancellation system is coupled in parallel with the pilot cancellation system 61 previously described, but without a desired traffic signal despreaders. A common input 147 is coupled to both systems 101, 61 with a common adder 149 which

-17-

is coupled to the outputs  $O, O_{add}$  from both systems 101, 61.

The pilot and unwanted traffic signals are subtracted from the desired traffic signal yielding an output 151 free of interference contributions by the pilot and plurality of transmitted traffic signals.

5

While specific embodiments of the present invention have been shown and described, many modifications and variations could be made by one skilled in the art without departing from the spirit and scope of the invention. The above description serves to illustrate and not limit the particular form in any way.

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\* \* \*

THE CLAIMS DEFINING THE INVENTION ARE AS FOLLOWS:

1. A cancellation system for removing selected signals from a traffic signal prior to decoding in a receiver that receives communication signals from a transmitter over a CDMA air interface, the system including:

a system input for receiving the communication signals;

said system input inputted as input to a traffic signal cancellation system having an output equal to the desired traffic signal minus the unwanted traffic signals;

said system input also inputted as input to a pilot signal cancellation system, the system processing the input to remove a global pilot signal and having an output equal to the desired traffic signal minus the global pilot signal; and

whereby the output of the pilot signal cancellation system is subtracted from the output of the traffic signal cancellation system to provide the cancellation system output.

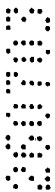
2. The cancellation system according to claim 1 wherein the traffic cancellation system [said selected signal canceler includes a desired traffic signal despreader coupled to a sum and dump processor to produce an output and an unwanted traffic signal canceler, the canceler including:

an unwanted traffic signal despreader having a signal input coupled to said system input and a summed output;

the unwanted traffic signal despreader including an unwanted traffic signal code generator and a mixer for mixing an output of the generator with the input to produce an unwanted traffic signal canceler output;

said unwanted traffic signal despreader summed output coupled to a hard decision processor having a phase output and a data output;

said hard decision processor phase output coupled to a low pass filter, said low pass filter having an output;



said low pass filter output coupled to an input of a processor that filters the product of the unwanted traffic signal to desired traffic signal cross-correlation outputting the unwanted traffic signal strength;

said processor output multiplied with said hard decision data output with a first multiplier having an output delivered to an adjustable amplifier;

an unwanted traffic code generator output coupled to an input of a complex conjugate processor having an output;

said complex conjugate output mixed with a complex conjugate of the desired traffic signal code by a first mixer having an output;

said first mixer output coupled to an input of a first sum and dump processor having an output;

said first sum and dump processor coupled to an input of an amplifier having an adjustable gain controlled by said multiplier output; and

said output of said amplifier is coupled to an adder which subtracts the output of each variable amplifier from the output of the desired traffic signal despreader to get the output of the traffic signal cancellation system.

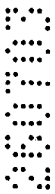
3. The cancellation system according to claim 1 wherein the pilot signal cancellation system includes:

a global pilot despreader coupled to said input having a summed output;

a desired traffic signal and global pilot cross-correlation means having an output;

said global pilot despreader output coupled to a pilot strength determining means, said determining means having an output;

said pilot strength determining means output multiplied with said cross-correlation means output; and



said multiplied product is said output.

4. The cancellation system according to claim 3 wherein said cross-correlation means includes:

a global pilot spreading code complex conjugate code generator;

a desired traffic signal complex conjugate code generator;

a second mixer for cross-correlating said global pilot signal code and said desired traffic signal complex conjugate code; and

a second sum and dump processor for summing over time said cross-correlation product.

5. The cancellation system according to claim 4 wherein said means to derive said global pilot signal strength further includes:

a low-pass filter having an output; and

a processor coupled to said low-pass filter deriving and outputting the global pilot signal strength.



6. A global pilot signal cancellation system for use in a receiver that receives communication signals from a transmitter over a CDMA air interface that removes the global pilot signal from a desired traffic signal prior to decoding, the system including:

an input for receiving the communication signals and a system output;

said input coupled to a global pilot despreader and a desired traffic signal despreader each having a summed output;

a desired traffic signal and global pilot cross-correlation means;

said global pilot despreader output coupled to a pilot strength determining means, said determining means having an output;





said pilot strength determining means output multiplied with said cross-correlation means output; and

said multiplied product subtracted from a summed output of said desired traffic signal despreaders output outputting the desired traffic signal free from the global pilot signal.

7. The global pilot signal cancellation system according to claim 6 wherein said means to derive said global pilot signal strength further includes:

a low-pass filter having an output; and

a processor coupled to said low-pass filter deriving and outputting the global pilot signal strength.

8. A traffic signal cancellation system for use in a receiver that receives communication signals from transmitter over a CDMA air interface that removes at least one unwanted traffic signal from a desired traffic signal prior to decoding, the system including:

an input for receiving the communication signals and a system output;

said input coupled to a desired traffic signal despreaders having a first summed output;

an at least one unwanted traffic signal canceler including:

an unwanted traffic signal despreaders having an input coupled to said first summed output and a second summed output;

the unwanted traffic signal despreaders including an unwanted traffic signal code generator and a mixer for mixing an output of the generator with the input to produce an unwanted traffic signal despreaders output;

said unwanted traffic signal despreaders summed output coupled to a hard decision processor having a phase output and a data output;

said hard decision processor phase output coupled to a low pass filter, said low pass filter having an output;

said low pass filter output coupled to an input of a processor that filters the product of the unwanted traffic signal to desired traffic signal cross-correlation outputting the unwanted traffic signal strength;

said processor output multiplied with said hard decision data output with a multiplier having an output delivered to an adjustable amplifier;

an unwanted traffic code generator output coupled to an input of a complex conjugate processor having an output;

said complex conjugate output mixed with a complex conjugate of the desired traffic signal code by a mixer having an output;

said mixer output coupled to an input of a second sum and dump processor having an output;

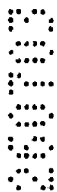
said second sum and dump processor coupled to an input of an amplifier having an adjustable gain controlled by said multiplier output; and

said output of said amplifier is coupled to an adder which subtracts the output of each variable amplifier from the output of the desired traffic signal despreader to get the output of the traffic cancellation system.



9. A cancellation system substantially as hereinbefore described with reference to Figures 2A to 7.

10. A global pilot cancellation system substantially as hereinbefore described with reference to Figures 2A to 7.



11. A traffic signal cancellation system substantially as herein before described with reference to Figures 2A to 7.

**DATED** this 26th day of June 2003  
**INTERDIGITAL TECHNOLOGY CORPORATION**

WATERMARK PATENT & TRADE MARK ATTORNEYS  
290 BURWOOD ROAD  
HAWTHORN VICTORIA 3122  
AUSTRALIA

PVF/MAP/TL5

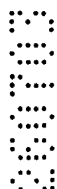
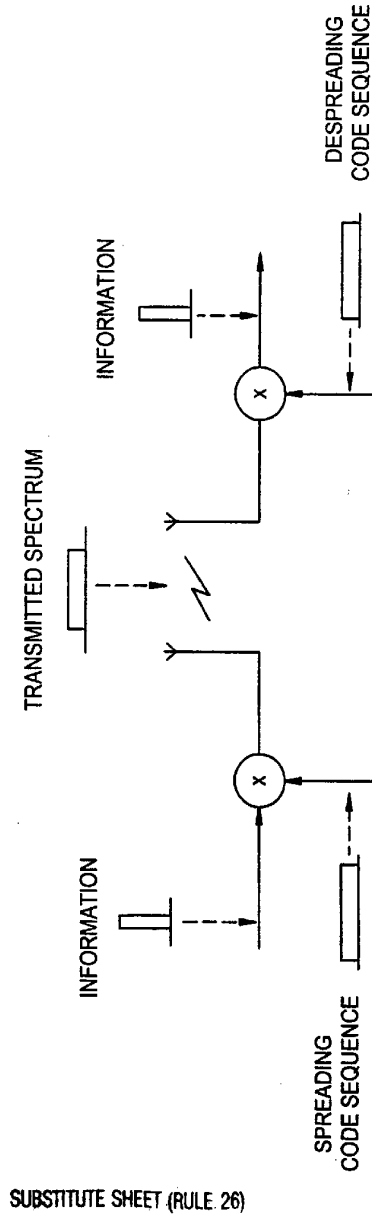


FIG. 1  
PRIOR ART



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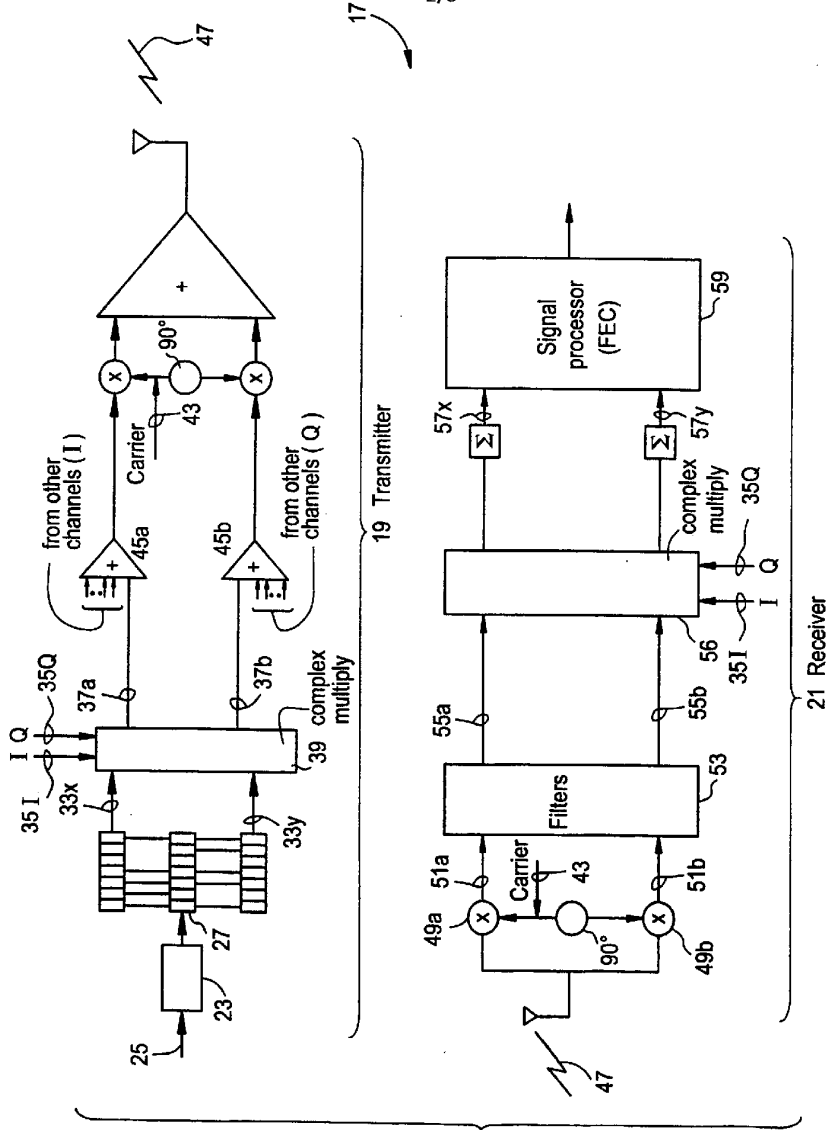
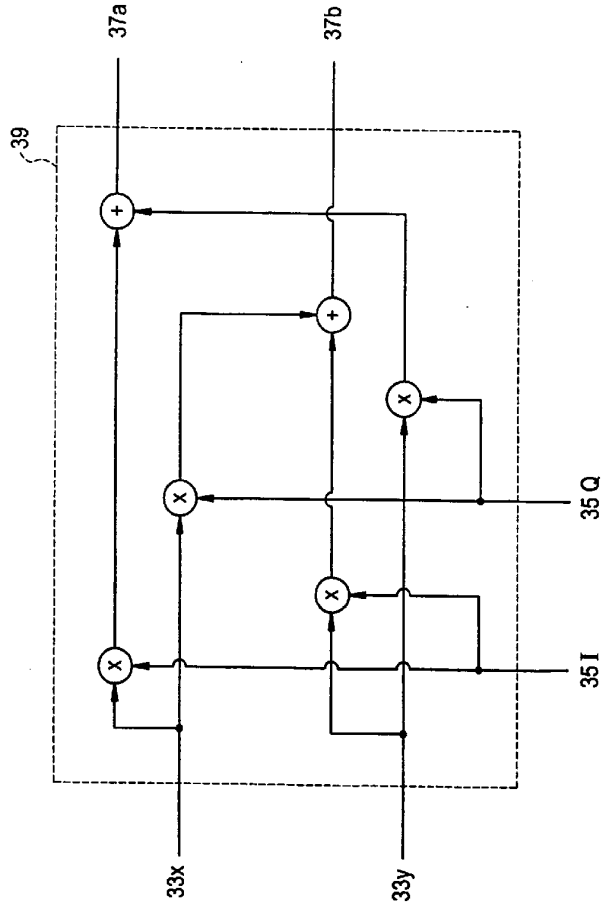


FIG. 2A

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FIG. 2B



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FIG. 3A

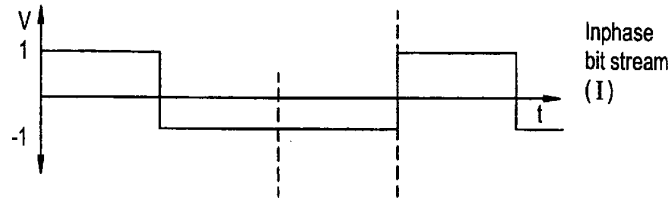


FIG. 3B

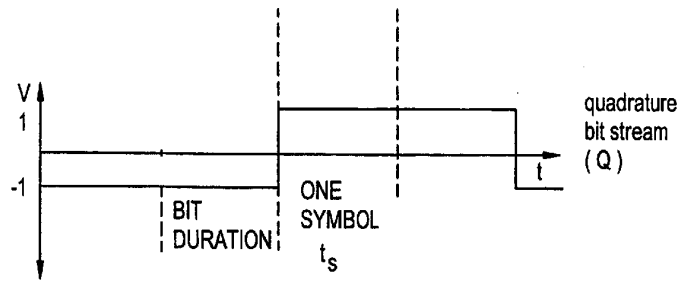
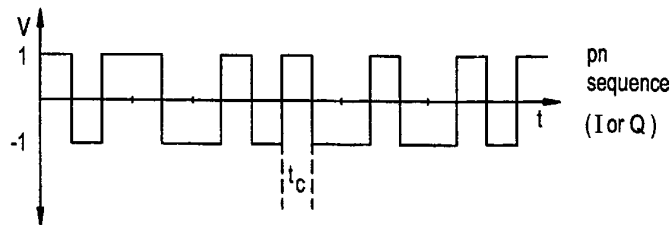
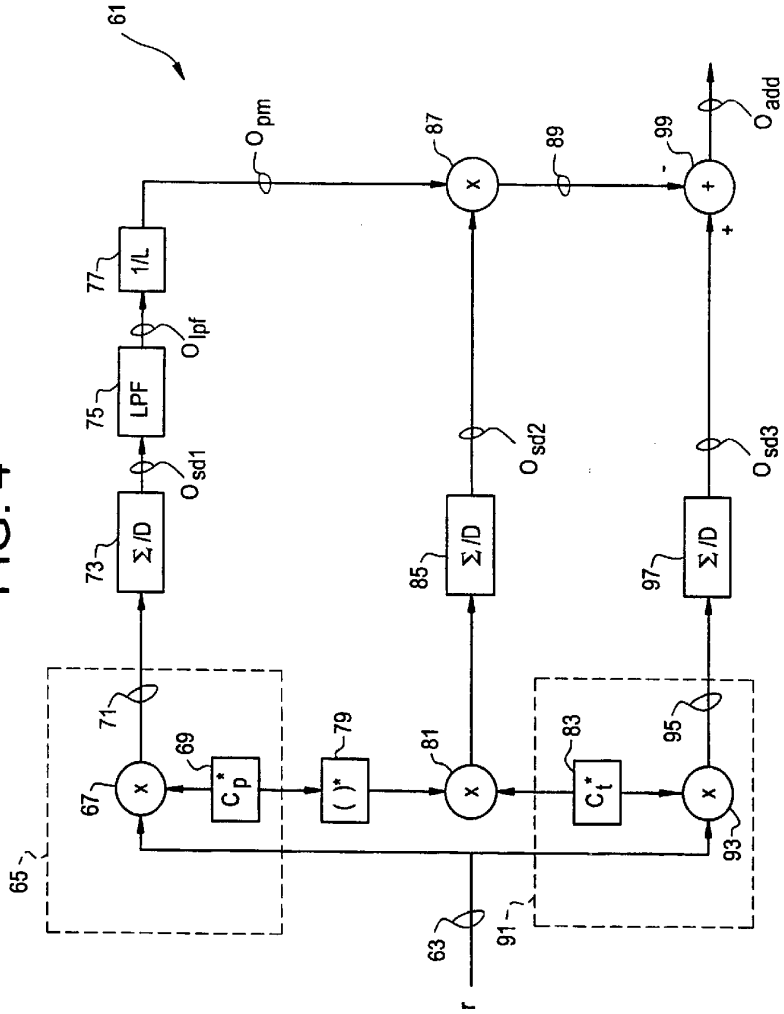


FIG. 3C



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FIG. 4

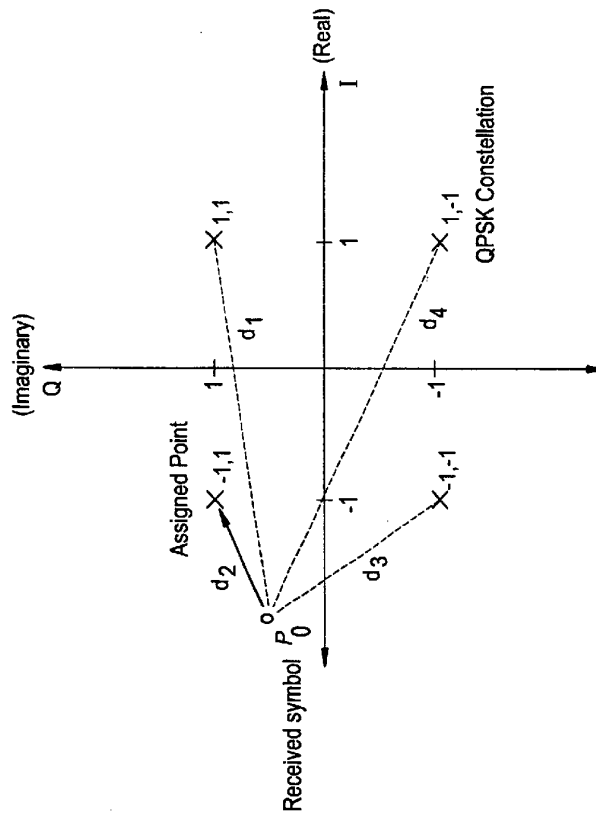


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FIG.6



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