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(54) **SYSTEMS AND METHODS FOR PARALLEL SIGNAL CANCELLATION**

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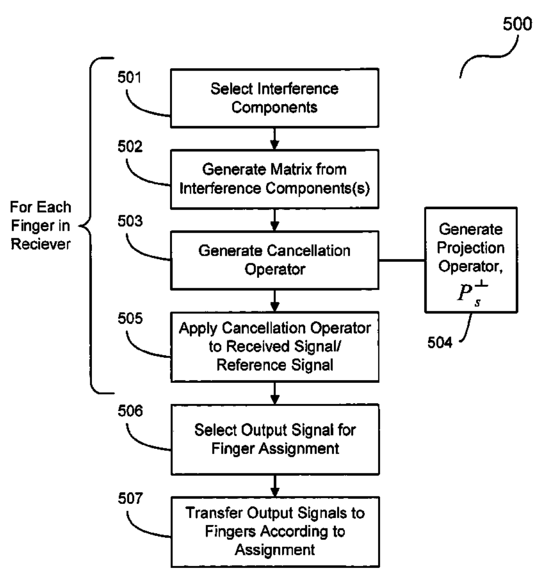
(57) **ABSTRACT**

The present invention provides systems and methods for parallel interference suppression. In one embodiment of the invention, a processing engine is used to substantially cancel a plurality of interfering signals within a received signal. The processing engine includes a plurality of matrix generators that are used to generate matrices, each matrix comprising elements of a unique interfering signal selected for cancellation. The processing engine also includes one or more processors that use the matrices to generate cancellation operators. A plurality of applicators applies the cancellation operators to parallel but not necessarily unique input signals to substantially cancel the interfering signals from the input signals. These input signals may include received signals, interference cancelled signals and/or PN codes.

46 Claims, 5 Drawing Sheets



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See application file for complete search history.

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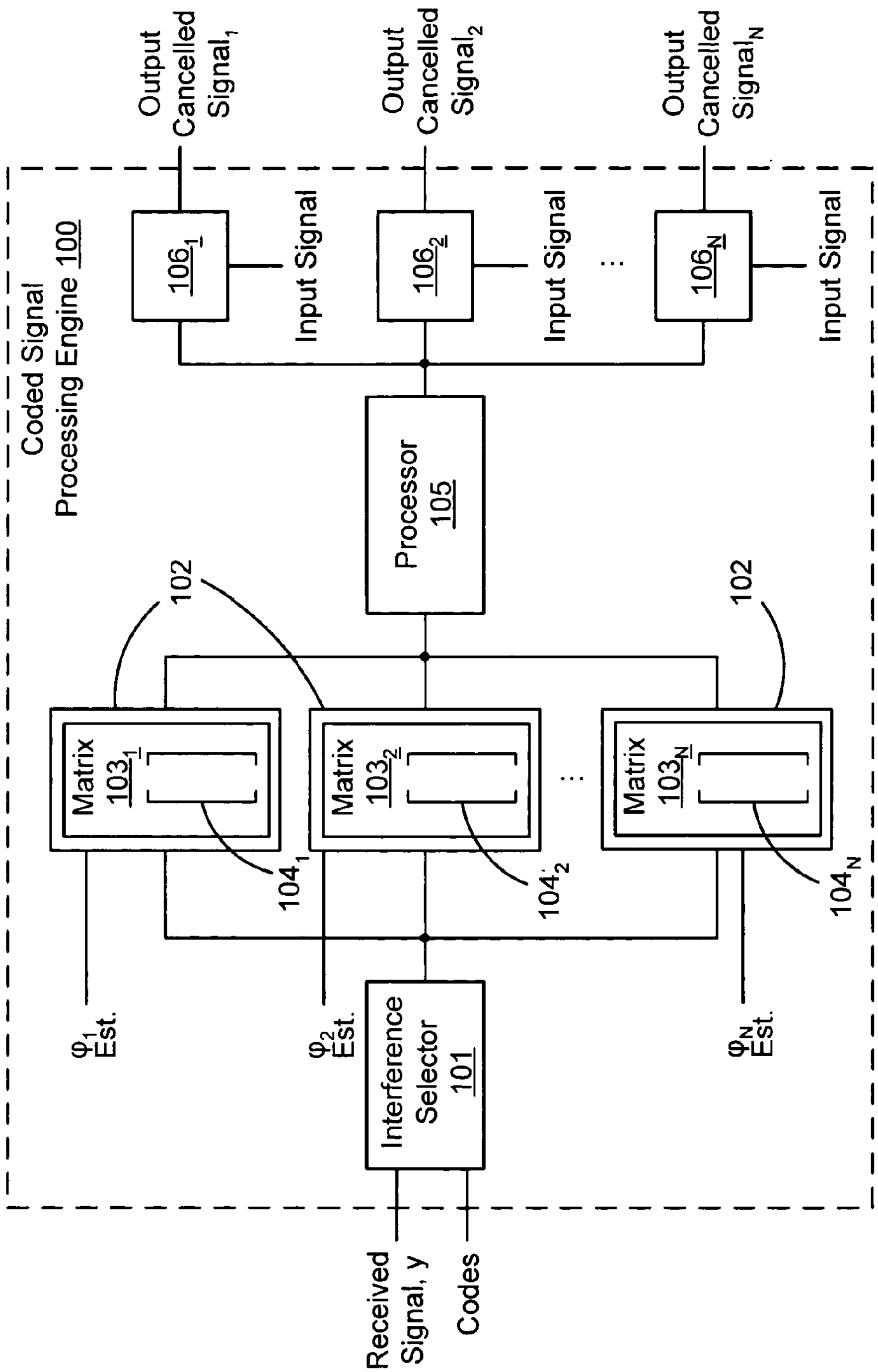
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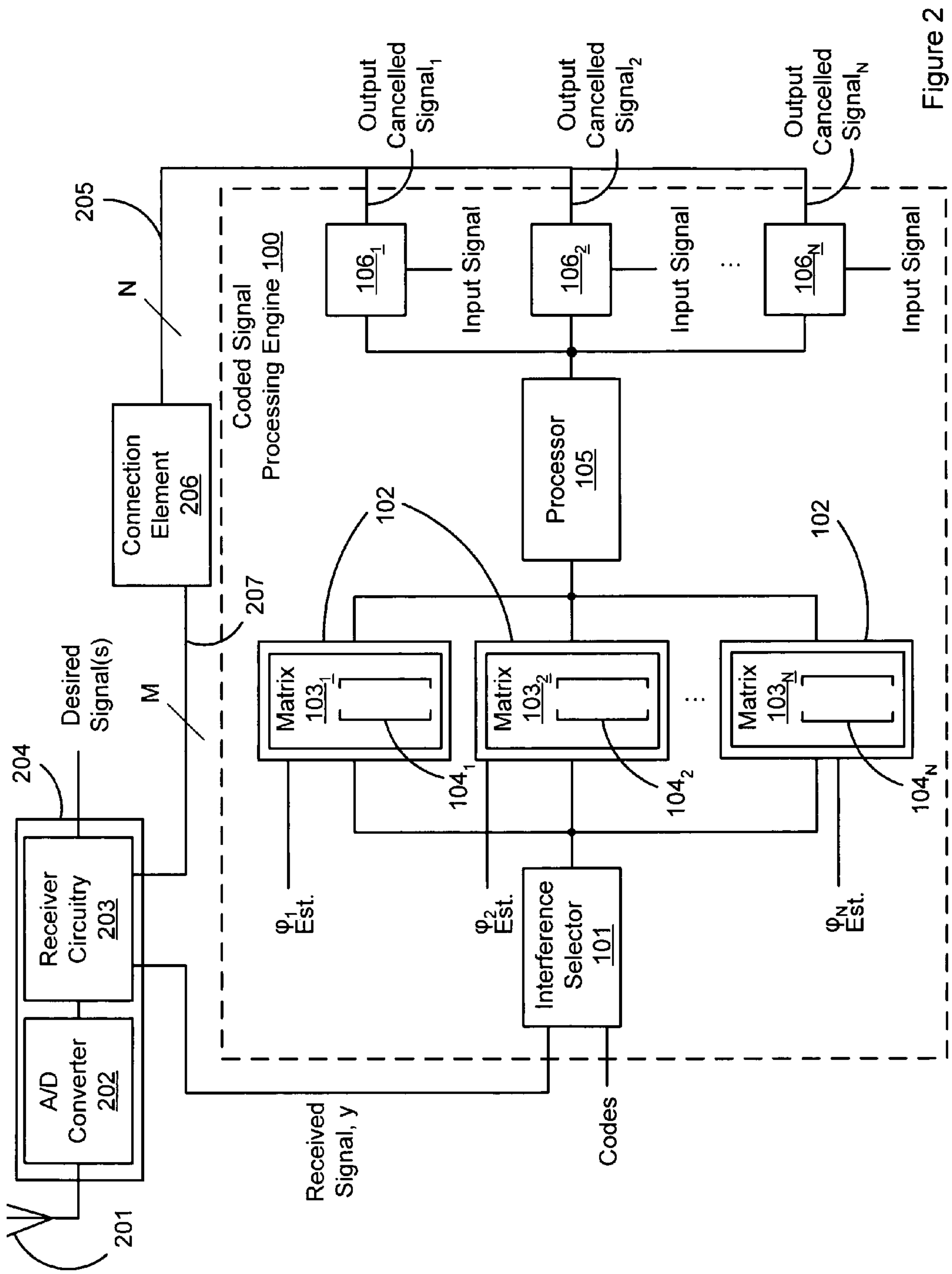
Output Cancelled Signal1
Output Cancelled Signal2
Output Cancelled SignalN
1061
1062
106N
Input Signal
Input Signal
Input Signal
Processor 105
102
102
Matrix 1031
Matrix 1032
Matrix 103N
1041
1042
104N
φ1 Est.
φ2 Est.
φN Est.
Interference Selector 101
Received Signal, y
Codes

Figure 1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Connection Element 206
205
N
207
M
Desired Signal(s)
204
Receiver Circuitry 203
A/D Converter 202
201
Received Signal, y
Codes
Interference Selector 101
Matrix 103_1
Matrix 103_2
Matrix 103_N
104_1
104_2
104_N
102
102
φ1 Est.
φ2 Est.
φN Est.
Processor 105
106_1
106_2
106_N
Input Signal
Input Signal
Input Signal
Output Cancelled Signal_1
Output Cancelled Signal_2
Output Cancelled Signal_N

Figure 2

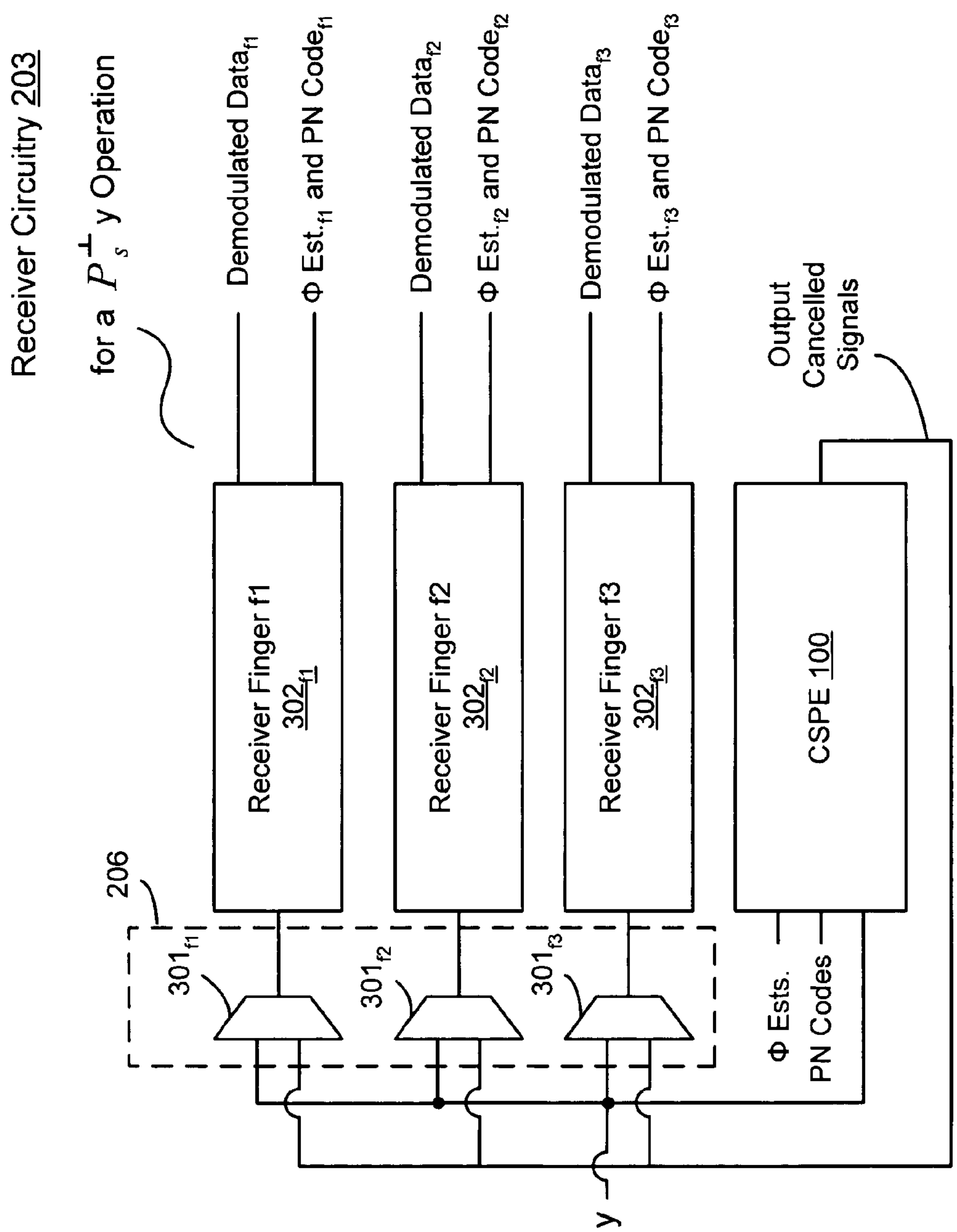
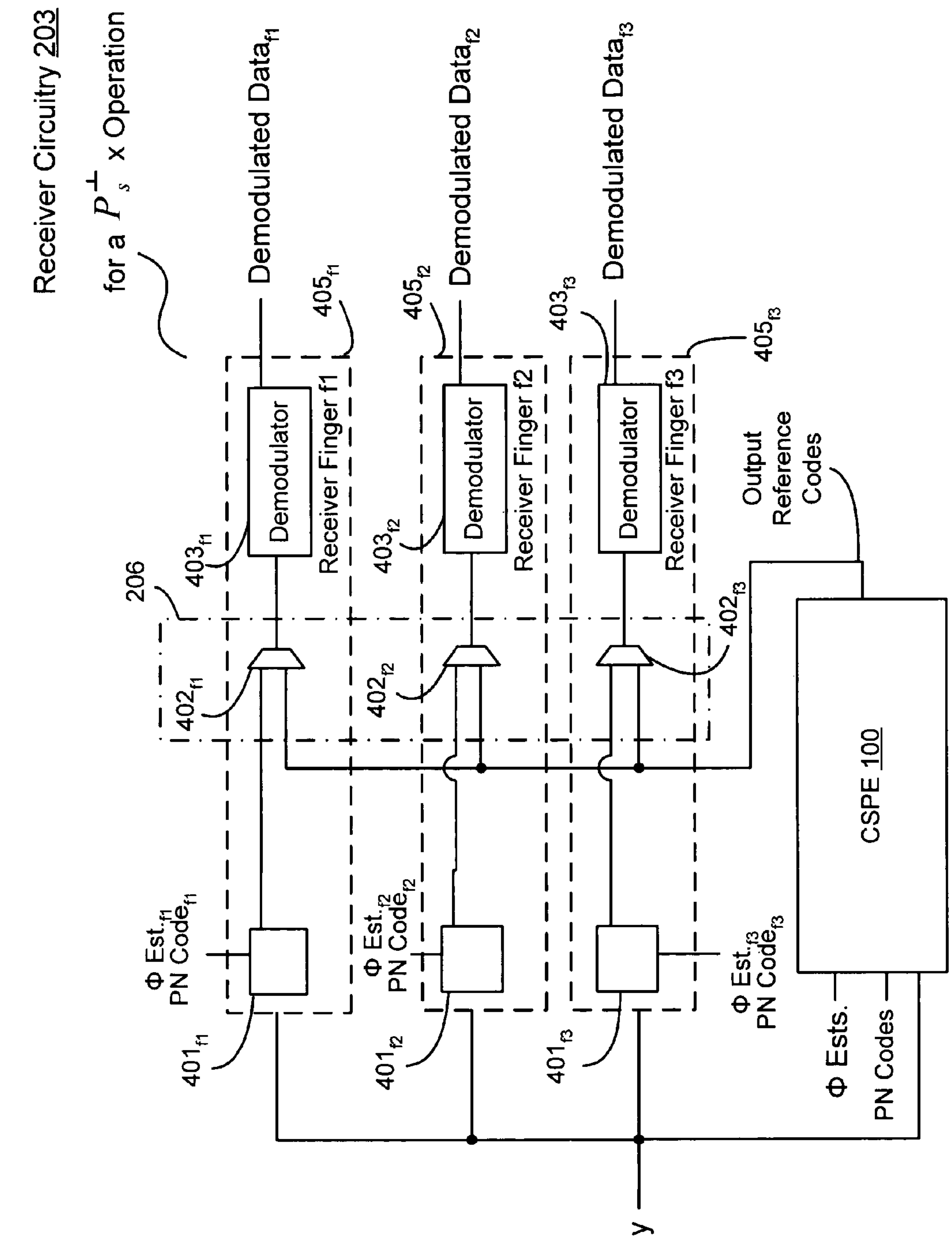

Receiver Circuitry 203
for a $P_s^{\perp}$ y Operation
Demodulated Data$_{f1}$
Φ Est.$_{f1}$ and PN Code$_{f1}$
Demodulated Data$_{f2}$
Φ Est.$_{f2}$ and PN Code$_{f2}$
Demodulated Data$_{f3}$
Φ Est.$_{f3}$ and PN Code$_{f3}$
Output Cancelled Signals
Receiver Finger f1 302$_{f1}$
Receiver Finger f2 302$_{f2}$
Receiver Finger f3 302$_{f3}$
CSPE 100
206
301$_{f1}$
301$_{f2}$
301$_{f3}$
Φ Ests.
PN Codes
y

Figure 3


Receiver Circuitry 203
for a $P_s^{\perp}$ x Operation
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Demodulated Data$_{f2}$
Demodulated Data$_{f3}$
405$_{f1}$
405$_{f2}$
405$_{f3}$
403$_{f1}$
403$_{f2}$
403$_{f3}$
Demodulator
Receiver Finger f1
Receiver Finger f2
Receiver Finger f3
206
402$_{f1}$
402$_{f2}$
402$_{f3}$
Output Reference Codes
CSPE 100
Φ Est.$_{f1}$
PN Code$_{f1}$
Φ Est.$_{f2}$
PN Code$_{f2}$
Φ Est.$_{f3}$
PN Code$_{f3}$
401$_{f1}$
401$_{f2}$
401$_{f3}$
Φ Ests.
PN Codes
y

Figure 4

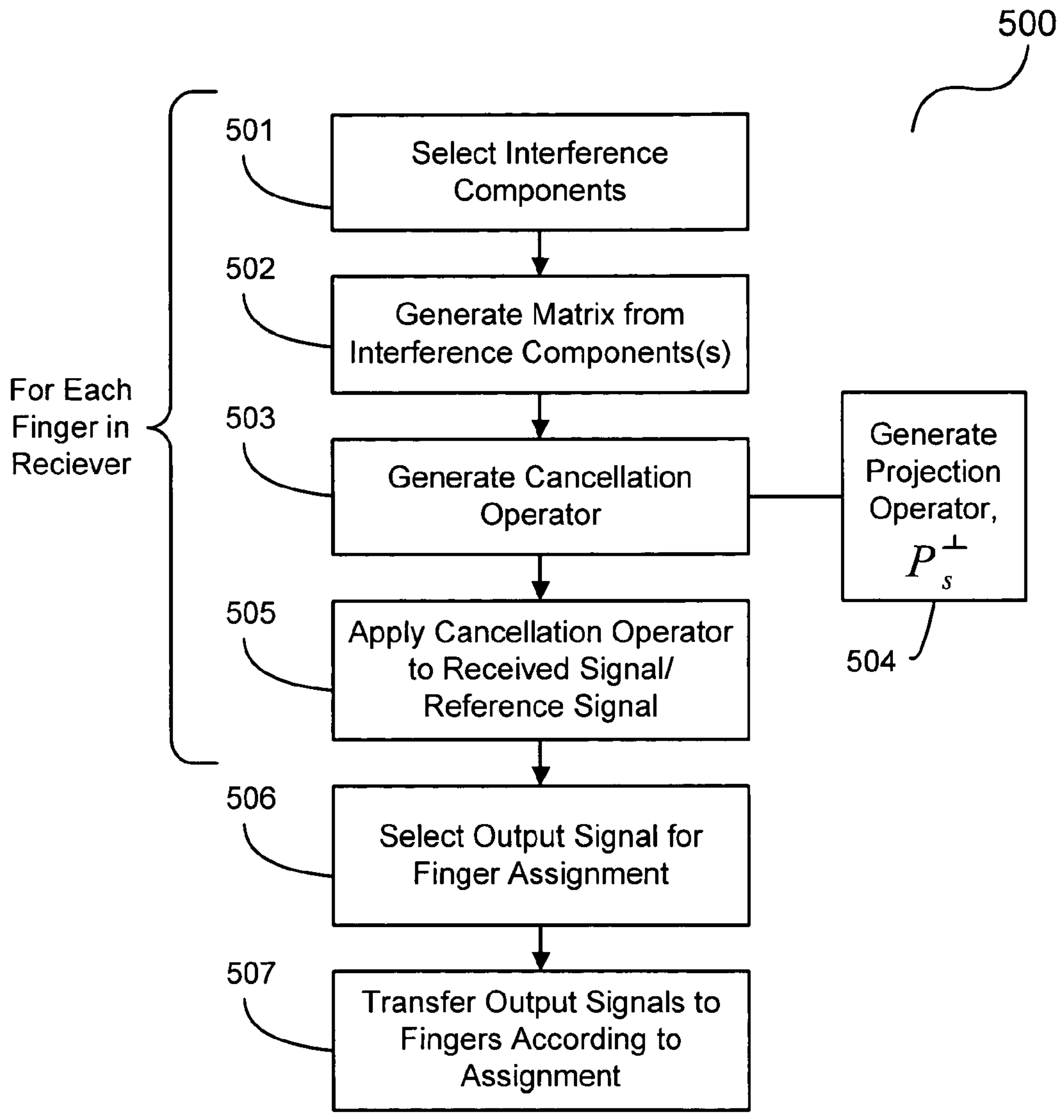
500
501
Select Interference Components
502
Generate Matrix from Interference Components(s)
503
Generate Cancellation Operator
Generate Projection Operator, $P_s^{\perp}$
504
For Each Finger in Reciever
505
Apply Cancellation Operator to Received Signal/ Reference Signal
506
Select Output Signal for Finger Assignment
507
Transfer Output Signals to Fingers According to Assignment

Figure 5

SYSTEMS AND METHODS FOR PARALLEL SIGNAL CANCELLATION

CROSS REFERENCE TO RELATED APPLICATIONS

This application claims priority to U.S. patent application Ser. No. 12/871,776, entitled "Advanced Signal Processors for Interference Cancellation in Baseband Receivers," and filed Aug. 30, 2010; which claims priority to U.S. patent application Ser. No. 11/204,606, entitled "Advanced Signal Processors for Interference Cancellation in Baseband Receivers," filed Aug. 15, 2005, and issued as U.S. Pat. No. 7,787,572; which claims priority to (1) U.S. patent application Ser. No. 11/192,763, entitled "Interference Cancellation Within Wireless Transceivers," filed Jul. 29, 2005, and issued as U.S. Pat. No. 7,463,609 and (2) U.S. patent application Ser. No. 11/100,935, entitled "Construction of Projection Operators for Interference Cancellation," filed Apr. 7, 2005, and published as U.S. Patent Application Publication Number 2005-0180364 A1, which claims priority to (a) U.S. patent application Ser. No. 10/773,777, entitled "Systems and Methods for Parallel Signal Cancellation," filed Feb. 6, 2004, and issued as U.S. Pat. No. 7,394,879, which is a continuation-in-part of U.S. application Ser. No. 10/763,346 filed Jan. 23, 2004, and issued as U.S. Pat. No. 7,039,136 on May 2, 2006; (b) U.S. patent application Ser. No. 10/686,359, entitled "System and Method for Adjusting Phase," filed Oct. 15, 2003, and issued as U.S. Pat. No. 7,068,706; (c) U.S. patent application Ser. No. 10/686,829, entitled "Method and Apparatus for Channel Amplitude Estimation and Interference Vector Construction," filed Oct. 15, 2003, and issued as U.S. Pat. No. 7,580,448; (d) U.S. patent application Ser. No. 10/294,834, entitled "Construction of an Interference Matrix for a Coded Signal Processing Engine," filed Nov. 15, 2002, and issued as U.S. Pat. No. 7,200,183; and (e) U.S. patent application Ser. No. 10/247,836, entitled "Serial Cancellation Receiver Design for a Coded Signal Processing Engine," filed Sep. 20, 2002, and issued as U.S. Pat. No. 7,158,559. The entirety of each of the foregoing patents, patent applications, and patent application publications is incorporated by reference herein.

BACKGROUND

1. Field of the Invention

The invention generally relates to the field of communications. More specifically the invention is related to interference suppression for use in coded signal communications, such as Code Division Multiple Access ("CDMA") communications.

2. Discussion of the Related Art

Interference in communications obstructs the intended reception of a signal and is a persistent problem. Interference may exist in many forms. In CDMA communications, for example, interference is typically the result of receiving one or more unwanted signals simultaneously with a selected signal. These unwanted signals may disrupt the reception of the selected signal because of mutual interference. This disruption of the selected signal is typical in CDMA telephony systems and may corrupt data retrieval processes of a selected signal.

In CDMA telephony, a communications system typically includes a plurality of "base stations" providing a coverage area within a geographic region. These base stations communicate with mobile telephones and/or other CDMA devices operating within the coverage area. To illustrate, a base station provides a coverage "cell" within the overall communication coverage area maintained by the communications system. While within a particular cell, a mobile telephone, or "handset", can communicate with the base station providing the coverage for that cell. As the mobile telephone moves to the cell of another base station, communications between the mobile telephone and the base station providing the initial cell coverage can be transferred via a "hand off" to the other base station.

Each base station within a CDMA telephony system uses coded signals to communicate with mobile telephones. For example, typical CDMA telephony systems use pseudorandom number (PN) spreading codes, sometimes referred to as "short codes," to encode data signals. These encoded data signals are transmitted to and from mobile telephones to convey digitized voice and/or other forms of communication. PN codes are known to those skilled in the art. The terms coded signals and encoded signals are interchangeably used herein.

To encode the data signals, the base station applies a PN code to the data at a rate faster than that of the data. For example, the PN code is applied to the data such that there are multiple "chips" of the code for any given element of data. Such an application of the PN code is commonly referred to as direct sequence spreading of the data. Chips and their associated chip rates are known to those skilled in the art.

Sometimes, each base station is assigned a particular timing offset of the short code to differentiate between base stations. Mobile telephones may therefore determine the identity of a particular base station based on the timing offset of the short code. Additionally, the data signals are often further encoded with a unique "covering" code. Such covering codes provide "channelization" for a signal that increases the number of unique communication channels. For example, data encoded with a covering code can further differentiate signals thereby improving detection and subsequent processing of a selected signal.

These covering codes are often used in CDMA telephony systems and typically include families of codes that are orthogonal (e.g., Walsh codes) or codes that are substantially orthogonal (e.g. quasi-orthogonal functions ("QOF")). Orthogonal covering codes and QOF covering codes have properties that allow for the differentiation of unwanted signals and are known to those skilled in the art. Walsh codes are also known to those skilled in the art.

Both the short codes and the covering codes assist in the detection of a selected signal. However, interference caused by other signals may still degrade data extraction capabilities of the selected signal. For example, as a mobile telephone communicates with a particular base station within that base station's coverage cell, signals from other base stations can interfere with the mobile telephone communication. Since cells often overlap one another to ensure that all desired geographic regions are included in the communication system's coverage area, one or more signals from one base station may interfere with the communication link, or "channel," between the mobile telephone and another base station. This effect is commonly referred to as cross-channel interference.

Cross-channel interference may also occur because some overhead channels are broadcast to all mobile telephones within the cell. These channels can "bleed" over into other cells and overpower a selected signal, thereby corrupting conveyed data. Examples of such channels include pilot channels, which are often broadcast at greater power levels and convey reference information and can be used to coherently demodulate other channels. Other potentially interfering channels may convey paging channels that alert a particular mobile telephone to an incoming call and synchronization channels that provides synchronization between a mobile telephone and a base station. Still other potentially interfering channels may include traffic channels bearing user traffic such as data and voice.

Still, other forms of interference may occur from "multipath" copies of a selected signal. Multipath can create interference because of the reception of copies of a selected signal at differing times. Multipath typically occurs because of obstructions, such as buildings, trees, et cetera, that create multiple transmission paths for a selected signal. These separate transmission paths may have unique distances that cause the signal to arrive at a receiver at differing times and is commonly referred to as co-channel interference. Additionally, these separate paths may bleed over into other cells to cause cross-channel interference.

Multipath creates co-channel interference because, among other reasons, the orthogonality of the covering code for a received signal is essentially lost due to timing offsets associated with the multipath. For example, a multipath signal having a covering code and arriving at a receiver at differing times causes a misalignment of the covering code. Such a misalignment can result in a high cross-correlation in the covering codes and a general inability to correctly retrieve conveyed data.

"Rake" receivers, such as those used in CDMA telephony systems, combine multipath signals to increase available signal strength. For example, a rake receiver may have a plurality of "fingers," wherein each finger of the rake receiver independently estimates channel gain and other signal characteristics (e.g., phase) of the selected signal to more accurately demodulate data of the selected signal and subsequently retrieve the data. Each finger is assigned a particular "path" of the selected signal (i.e., one of the paths of the multipath signal or a signal from another base station). These paths may be combined to increase signal strength. Additionally, as signal characteristics change, the fingers may be assigned or de-assigned to other "paths" of the signal to improve data retrieval.

Rake receivers can improve data retrieval of a received signal. However, present rake receivers do not substantially reduce cross-channel interference and/or co-channel interference. These interferers may still corrupt data as long as they exist in any substantial form.

SUMMARY

The present invention provides systems and methods for parallel interference suppression. In one embodiment of the invention, a processing engine is used to substantially cancel a plurality of interfering components within a received signal. The processing engine includes a plurality of matrix generators that are used to generate matrices, each matrix comprising elements of a unique component selected for cancellation. The processing engine also includes one or more processors that use the matrices to generate cancellation operators. A plurality of applicators applies the cancellation operators to parallel but not necessarily unique input signals to substantially cancel the interfering components from the input signals. These input signals may include received signals, interference cancelled signals and/or PN codes. The embodiments disclosed herein may be particularly advantageous to systems employing CDMA (e.g., such as cdmaOne and cdma2000), Wideband CDMA, Broadband CDMA and Global Positioning System ("GPS") signals. Such systems are known to those skilled in the art.

In one embodiment of the invention, a processing engine comprises:

a plurality of matrix generators, wherein each matrix generator is configured for generating a matrix comprising elements of an interfering signal selected for cancellation;

a processor communicatively coupled to the matrix generators and configured for generating a cancellation operator from each matrix; and

a plurality of applicators, wherein each applicator is communicatively coupled to the processor and configured for applying one of the cancellation operators to an input signal to substantially cancel one of the interfering signals.

In another embodiment of the invention, the processing engine is configurable with a receiver and wherein the processing engine further comprises a connection element configured for receiving output signals from the applicators and for selecting received said output signals as inputs to processing fingers of the receiver.

In another embodiment of the invention, the connection element comprises a plurality of selectors wherein each selector is configured for receiving one of the output signals and for selecting said one of the output signals as one of the inputs to one of the processing fingers.

In another embodiment of the invention, each selector is further configured for receiving a digitized radio signal comprising one or more Code Division Multiple Access signals as one of the inputs to one of the processing fingers.

In another embodiment of the invention, each selector is further configured for receiving a digitized radio signal comprising one or more Wideband Code Division Multiple Access signals as one of the inputs to one of the processing fingers.

In another embodiment of the invention, each selector is further configured for receiving a digitized radio signal comprising one or more Global Positioning System signals as one of the inputs to one of the processing fingers.

In another embodiment of the invention, the output signals are interference cancelled signals.

In another embodiment of the invention, each cancellation operator is a projection operator configured for projecting a selected signal substantially orthogonal to one of the interfering signals.

In another embodiment of the invention, the projection operator comprises the form:

$$P_s^{\perp}=I-S(S^TS)^{-1}S^T,$$

where $P_s^{\perp}$ is the projection operator, I is an identity matrix, S is one of the matrices and S^T is a transpose of said one of the matrices.

In another embodiment of the invention, each of the cancellation operators comprises the form:

$$y'=y-S(S^TS)^{-1}S^Ty,$$

where y' is an output cancelled signal, y is a received signal, S is one of the matrices and S^T is a transpose of said one of the matrices.

In another embodiment of the invention, the processing engine further comprises an interference selector configured for selecting the interfering signals as inputs to the matrix generators.

In another embodiment of the invention, the interference selector is further configured for providing on-time interfering PN codes of the interfering signals to the matrix generators.

In another embodiment of the invention, the interference selector selects the interfering signals based on a pre-determined criteria selected from a group consisting of amplitude, timing offset, phase and code sequence.

In one embodiment of the invention, a method of canceling interference comprises:

generating a plurality of matrices, each matrix comprising elements of an interference signal selected for cancellation;

generating a cancellation operator from each of the matrices; and

applying each cancellation operator in parallel to an input signal to substantially cancel one of the interference signals.

In another embodiment of the invention, generating the cancellation operator comprises generating a projection operator having a form:

$$P_s^{\perp}=I-S(S^TS)^{-1}S^T,$$

where $P_s^{\perp}$ is the projection operator, I is an identity matrix, S is one of the matrices and S^T is a transpose of said one of the matrices.

In another embodiment of the invention, applying comprises substantially canceling said one of the interfering signals according to the form:

$$y'=y-S(S^TS)^{-1}S^Ty,$$

where y' is an output cancelled signal, y is a received signal, S is one of the matrices and S^T is a transpose of said one of the matrices.

In another embodiment of the invention, the method further comprises selecting the interference signals for input to the matrices.

In another embodiment of the invention, the method further comprises providing on-time interfering PN codes of the interfering signals to the matrices in response to selecting.

In another embodiment of the invention, the method further comprises selecting output signals generated in response to applying, for assignment of the output signals to processing fingers of a receiver.

In another embodiment of the invention, the method further comprises transferring the output signals to the processing fingers in response to selecting said output signals as input signals to the processing fingers.

In another embodiment of the invention, the output signals are interference cancelled signals.

In another embodiment of the invention, the method further comprises receiving a Code Division Multiple Access signal.

In another embodiment of the invention, the method further comprises receiving a Wideband Code Division Multiple Access signal.

In another embodiment of the invention, the method further comprises receiving a Global Positioning System signal.

In one embodiment of the invention, a mobile handset comprises:

a receiver configured for receiving a radio signal; and

a processing engine communicatively coupled to the receiver and comprising

a plurality of matrix generators, wherein each matrix generator is configured for generating a matrix comprising elements of an interfering signal selected for cancellation,

a processor communicatively coupled to the matrix generators and configured for generating a cancellation operator from each matrix, and

a plurality of applicators, wherein each applicator is communicatively coupled to the processor and configured for applying one of the cancellation operators to an input signal to substantially cancel one of the interfering signals.

In another embodiment of the invention, the radio signal comprises a Code Division Multiple Access signal.

In another embodiment of the invention, the radio signal comprises a Wideband Code Division Multiple Access signal.

In another embodiment of the invention, the radio signal comprises a Global Positioning System signal.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a block diagram of an exemplary coded signal processing engine in one embodiment of the invention.

FIG. **2** is a block diagram of the exemplary coded signal processing engine configurable with a receiver in one embodiment of the invention.

FIG. **3** is a block diagram of exemplary receiver circuitry.

FIG. **4** is another block diagram of exemplary receiver circuitry.

FIG. **5** is a flow chart illustrating one exemplary methodical embodiment of the invention.

DETAILED DESCRIPTION OF THE DRAWINGS

While the invention is susceptible to various modifications and alternative forms, specific embodiments thereof have been shown by way of example in the drawings and are herein described in detail. It should be understood, however, that it is not intended to limit the invention to the particular form disclosed, but rather, the invention is to cover all modifications, equivalents, and alternatives falling within the spirit and scope of the invention as defined by the claims.

FIG. **1** is a block diagram of exemplary coded signal processing engine **100** in one embodiment of the invention. Coded signal processing engine ("CSPE") **100** is used to substantially cancel interfering components from signals. Examples of such interfering components include co-channel interference and cross-channel interference typical of CDMA telephony. CSPE **100** substantially cancels selected interfering components by applying a cancellation operator to either a received signal y or selected coded reference signals. CSPE **100** thereby generates a plurality of output cancelled signals (i.e., labeled Output Cancelled $\text{Signals}_{1 \ldots N}$, where "N" is an integer greater than one), wherein the selected interfering components are substantially removed from the received signal y/coded reference signals. The coded reference signals may be "on-time" PN codes of signals used to decode signals selected for demodulation. On-time as used herein refers to a particular timing alignment for a PN code. Such a timing alignment may be relevant to extracting data from a signal being tracked within a receiver.

In this embodiment, CSPE **100** includes interference selector **101** for selecting interfering components and for providing selected "on-time" interfering PN codes to matrix generators **102** of CSPE **100**. The interference selector may select the interfering signals based on pre-determined criteria, such as amplitude, timing offset, phase and/or code sequence. Matrix generators **102** are configured for using selected interfering codes and phase estimates (labeled $\phi_{1 \ldots N}$ Est.) corresponding to those codes to generate matrices **103** (labeled matrices $\mathbf{103}_{1 \ldots N}$). Each matrix **103** comprises one or more vectors **104** (labeled matrices $\mathbf{104}_{1 \ldots N}$). Further, the vectors **104** comprise elements representing components of the interfering codes (e.g., such as those elements described in the '346 and the '360 applications).

For example, each vector may include elements representing a unique code of an interfering signal (e.g., co-channel interference or cross-channel interference). The codes are typically Walsh covering codes and on-time PN codes of selected interferers. Each interference vector is multiplied by a phase estimate of a corresponding selected interferer. Phase estimation is exemplified in the '346 application.

As multiple vectors **104** may be used to represent multiple interfering signals, each matrix **103** may be representative of a unique plurality of interfering signals. For example, matrix $\mathbf{103}_1$ may include a single vector representing one interfering signal A_1 (not shown), whereas matrix $\mathbf{103}_2$ may include a single vector representing another interfering signal A_2 (not shown). The invention, however, is not intended to be limited to the exemplary embodiment shown herein.

CSPE **100** uses each matrix **103** to generate unique cancellation operators for selective cancellation of the interfering components. Accordingly, CSPE **100** includes processor **105** configured for processing matrices **103** to generate the cancellation operators. The cancellation operators may be projection operators that are used to project selected coded signals substantially orthogonal to the interference (e.g., the interference represented by the matrices **103**) so as to substantially cancel or remove the interference from the selected coded signals. In a projection operator embodiment, processor **105** uses matrices **103** to generate the projection operators according to the following form:

$$P_s^{\perp}=I-S(S^TS)^{-1}S^T, \quad \text{(Eq. 1)}$$

where $P_s^{\perp}$ is the projection operator, I is an identity matrix, S is an interference matrix **103** and S^T is a transpose of the matrix **103**. Such projection operators and their associated constructions are described in the '346, the '360, the '829, the '219 and the '834 applications.

CSPE **100** applies the cancellation operator to selected input signals (labeled "Input Signal"). Each applicator **106** (labeled $\mathbf{106}_{1 \ldots N}$) applies one of the cancellation operators to an input signal. Each application of a cancellation operator typically provides a unique output cancelled signal which is the input signal with the selected interfering signal substantially removed. For example, using the same signal notations of "A" as described above, applicator $\mathbf{106}_1$ may apply a projection operator $P_{s\ A1}^{\perp}$ to an input signal. The projection operator $P_{s\ A1}^{\perp}$, in this example, is generated from a matrix **103** comprising an interfering component of signal A_1. Once applied to the received signal y as the input signal, applicator $\mathbf{106}_1$ produces an Output Cancelled Signal_1 that corresponds to $y_{A1}'=P_{s\ A1}^{\perp}y$, where y_{A1}' is the received signal with the interfering component A_1 substantially removed.

Similarly, applicators $\mathbf{106}_2$ and $\mathbf{106}_N$ may apply projection operators in parallel with applicator $\mathbf{106}_1$ to produce the respective unique signals Output Cancelled Signal_2 and Output Cancelled Signal_N. For example, applicator $\mathbf{106}_2$ may apply a projection operator $P_{s\ A2}^{\perp}$ such that the applicator produces an Output Cancelled Signal_2 corresponding to $y_{A2}'=P_{s\ A2}^{\perp}y$, where y_{A2}' is the received signal with the interfering component A_2 substantially removed. Parallel as used herein implies the substantially simultaneous generations of unique cancellation operators and the subsequent applications of the cancellation operators to independent input signals.

In an alternative embodiment, cancellation may be performed by applying a construction of the matrices as follows:

$$y'=y-S(S^TS)^{-1}S^Ty. \quad \text{(Eq. 2)}$$

In such an embodiment, the received signal y is multiplied by the interference matrix construction of Eq. 1. However, that product is subtracted from the received signal y to produce an output cancelled signal y', such as y_{A1}' and y_{A21}'. Those skilled in the art should readily recognize that the two approaches produce substantially the same result.

While one exemplary embodiment has been shown in detail, the invention is not intended to be limited to the examples described and illustrated herein. For example, applicators **106** may apply other cancellation operators to other input signals to produce a variety of output cancelled signals. One example of another input signal is an on-time reference PN code, such as that described below in FIG. **4**. Examples of other methods for the production of cancellation operators include subtractive methods, decorrelators and decision feedback.

Additionally, the invention is not intended to be limited to the number of applicators **106**, input signals, output cancelled signals, matrix generators **102** and processors **105**. For example, processor **105** may be either a single processor configured for generating a plurality of cancellation operators or processor **105** may represent a plurality of processors each of which is similarly configured for generating a unique cancellation operator. Examples of such processors include general purpose processors and Application Specific Integrated Circuits ("ASIC"). Accordingly, the processor may be operably controlled via software and/or firmware instructions to generate the cancellation operators. Those skilled in the art are familiar with processors, ASICs, software, firmware and the various combinations thereof which may be used in such implementations.

Moreover, those skilled in the art should readily recognize that CSPE **100** in general as described herein may be implemented through software, firmware, hardware and/or various combinations thereof. For example, the generations of the cancellation operators and the subsequent cancellations of interfering signals may be computed through the use of software instructions (e.g., firmware) operable within a processor or specified in hardware architecture.

FIG. **2** is a block diagram of the exemplary CSPE **100** of FIG. **1** configurable with receiver **204** in one embodiment of the invention. In this embodiment, receiver **204** receives a radio frequency ("RF") signal through antenna **201** and subsequently converts that signal to a digital received signal y using Analog-to-Digital ("A/D") converter **202**. A/D converter **202** transfers the digital signal to receiver circuitry **203** for signal processing. Those skilled in the art should readily recognize that the processing of CDMA signals typically includes both In-phase ("I") and Quadrature ("Q") components. As such, the digital received signal y may include both I and Q components as well.

In this embodiment, receiver circuitry **203** is configured for transferring the digitized received signal y to CSPE **100** for cancellation of interfering signals. CSPE **100** receives the signal y as well as known codes from the interfering signals. For example, the interfering signals may be cross channel and/or co-channel interfering signals comprising known codes of CDMA telephony systems. Such codes may be input to CSPE **100** on an as needed basis or stored within a memory (not shown) local to the CSPE **100**. Alternatively, the codes may be generated by processor **105** on an as needed basis.

Operable characteristics of CSPE **100** are the same as those described in FIG. **1**. However, again using the same signal notations of "A" as described above, in this preferred receiver embodiment, CSPE **100** uses applicators $106_{1 \ldots N}$ to apply cancellation operators to the input signals in the following manner:

Applicator 106_1 produces an Output Cancelled $Signal_1$ that corresponds to $y_{A1}'=P_{s\ A1}^{\perp}y$, where again y_{A1}' is the received signal with the interfering component A_1 substantially removed;

Applicator 106_2 produces an Output Cancelled $Signal_2$ corresponding to $y_{A2}'=P_{s\ A2}^{\perp}y$; and where again y_{A2}' is the received signal with the interfering component A_2 substantially removed.

These Output Cancelled $Signal_{1 \ldots N}$ are transferred to connection element **206** via "N" channel connection **205**. For example, "N" channel connection **205** may be a communicative connection such as a data bus that allows for the transfer of "N" number of channels to connection element **206**. Consequently, connection element **206** may be configurable to receive such an "N" channel connection.

Connection element **206** is configured for selectively transferring Output Cancelled $Signal_{1 \ldots N}$ to receiver circuitry **203** of receiver **204** via "M" channel connection **207**. For example, connection element **206** may be a switching device, multiplexer, a plurality of multiplexers or another similar communication device that selectively transfers "N" number of signals to "M" number of channels, where "M" is also a number greater than one. As such, "M" channel connection **207** is similar to "N" channel connection **205**.

The control for connection element **206** may be applied independently of cancellation processing. Consequently, connection element **206** may or may not be configured within the CSPE **100**. For example, should the selection of Output Cancelled $Signal_{1 \ldots N}$ be received by receiver circuitry **203** be decided by receiver **204**, then connection element **206** may reside outside of the embodied CSPE **100**. In a preferred embodiment, however, CSPE **100** includes the control functionality for connection element **206** that determines which of the Output Cancelled $Signal_{1 \ldots N}$ are transferred to receiver circuitry **203**. Accordingly, the invention should not be limited to the preferred embodiment described and shown herein.

FIG. **3** is a block diagram of exemplary receiver circuitry **203**. In this embodiment, receiver circuitry **203** is configured with CSPE **100** via connection element **206** for selectively tracking signals through receiver fingers **f1**, **f2** and **f3** (labeled 302_{f1}, 302_{f2} and 302_{f3}). For example, connection element **206** may allow the receiver circuitry **203** to track and subsequently demodulate a selected combination of Output Cancelled $Signal_{1 \ldots N}$ and the received signal y through the receiver fingers **f1**, **f2** and **f3**.

In a preferred embodiment, a first receiver finger **f1** receives the signal y via a corresponding selector (the selectors are labeled $301_{f1 \ldots f3}$). The phase estimate ϕ_{f1} and the PN $code_{f1}$ outputs of the first receiver finger flare transferred from the finger to CSPE **100** for producing the output cancelled signal y_{A1}' described in FIGS. **1** and **2**. A second receiver finger f2 selectively receives either y or y_{A1}' via a corresponding selector for tracking of a second assigned signal. If y is transferred to the second receiver finger **f2**, the phase estimate ϕ_{f2} and the PN code outputs of that second receiver finger are transferred to CSPE **100** to produce the output cancelled signal y_{A2}' also described in FIGS. **1** and **2**. Consequently, a third receiver fingers f3 has a selection of signals y and output cancelled signals y_{A1}' and y_{A2}' to track and demodulate a third assigned signal.

In many instances, tracking, demodulation and cancellation of the signals described and shown herein the preferred embodiment is all that is necessary in CDMA telephony because there are typically only one or two signals (e.g., A**1** and A**2**) that degrade reception beyond the point of intended data recovery. Accordingly, selective cancellation of only one or two signals may decrease processor consumption requirements and thereby improve overall processing performance of the system. As such, the embodiment should not be limited to the number of receiver fingers shown and described. More receiver fingers than those illustrated in this exemplary embodiment may be used to selectively track and demodulate signals according to the principles described herein.

FIG. **4** is another block diagram of exemplary receiver circuitry **203**. In this alternative embodiment, the received signal y is transferred to receiver fingers f**1**, f**2** and f**3** (labeled $405_{f1 \ldots f3}$) and CSPE **100**. Time tracking and phase estimation of the received signal y may be performed for each finger in corresponding elements $401_{f1 \ldots f3}$. Such tracking and phase estimation is used to generate on-time reference PN codes (PN $code_{f1 \ldots f3}$) and is described in greater detail in the '346 application. Elements $401_{f1 \ldots f3}$ transfer the on-time reference PN codes as well as the phase estimates (labeled $\phi_{f1 \ldots f3}$) to CSPE **100** and to corresponding selectors $402_{f1 \ldots f3}$. CSPE **100** uses these on-time PN codes and phase estimates to generate cancellation operators that remove interfering signals from the received signal y.

Differing from the embodiment of FIG. **3**, CSPE **100** uses the applicators **106** of FIGS. **1** and **2** to apply cancellation operators to the on-time PN codes to produce output cancelled versions of the codes (labeled output reference codes). Such an embodiment may conform to a cancellation of the form $P_s^{\perp}x$, where x is an on-time reference PN code. These output cancelled reference codes are selectively transferred to demodulators $403_{f1 \ldots f2}$ via selectors $402_{f1 \ldots f2}$ of connection element **206**. These codes are used by the demodulators $403_{f1 \ldots f2}$ to demodulate the received signal y. Such demodulation may be performed with a correlation of a reference code and a received signal over a period of a symbol and is well known to those skilled in the art.

In a preferred embodiment, a first receiver finger **f1** receives the on-time reference PN code x_{f1} via a first selector 402_{f1} and produces the phase estimate ϕ_{f1} and the PN $code_{f1}$ outputs. The first finger f1 then demodulates the received signal y using the code x_{f1}. These phase estimate ϕ_{f1}, and the PN $code_{f1}$ outputs of that first receiver finger f1 may be transferred from the finger f1 to CSPE **100** for producing the output cancelled signal x_{A1}', where x_{A1}' is the on-time reference PN code of the signal selected for demodulation without the interfering effects of the signal A**1**. A second receiver finger f2 selectively receives either x or x_{A1}' via corresponding selector 402_{f2}. If x is transferred to the second receiver finger **12**, the phase estimate ϕ_{f2} and the PN code outputs of receiver finger f2 are transferred to CSPE **100** to produce the output cancelled signal x_{A2}', where x_{A2}' is the on-time reference PN code of the signal selected for demodulation without the interfering effects of the signal A**2**. Consequently, a third receiver finger f3 has a selection of signals x_{f3} and output cancelled on-time reference PN codes x_{A1}' and x_{A2}' which can be used to track and demodulate the received signal y.

Again, those skilled in the art should readily recognize that the preferred embodiment should not be limited to that which is shown and described herein. More receiver fingers than those illustrated and described herein the exemplary embodiment may be used to selectively track and demodulate signals according to the principles described herein.

FIG. **5** is a flow chart **500** illustrating one exemplary methodical embodiment of the invention. In this embodiment, one or more interference components of a received signal are selected, in element **501**. These interference components are used to generate an interference matrix, in element **502**. A cancellation operator is generated from the interference matrix, in element **503**. The cancellation operator may be a projection operator as described in FIG. **1** that is generated in element **504** to substantially orthogonally project a received signal from interfering components. Such a projection operator may substantially cancel or remove the interfering components from the received signal. The cancellation operator is applied to either the received signal or an on-time reference PN code, in element **505**.

Elements **501** through **505** are performed in parallel based on the number of receiver fingers used for tracking and demodulation in a receiver. For example, in a receiver comprising three fingers, such as the receiver circuitry **203** in FIGS. **4** and **5**, elements **501** through **505** may be performed three times in a substantially simultaneous fashion. Moreover, control functionality may be configured to only select information of particular fingers. For example, if a signal does not contribute significantly to the interference, it may be selectively excluded from the cancellation process to decrease processing. Such a selection process is described in the '954 application.

The application of the cancellation operators in element **505** produces output cancelled signals such as those described herein. Once those output cancelled signals are produced, the signals are selected for finger assignments, in element **506**. Such a selection process may be performed by connection element **206** in FIG. **3**. Selected output cancelled signals are transferred to the receiver fingers according to their respective finger assignments, in element **507**. Within their respective fingers, the output cancelled signals are either tracked and demodulated as in FIG. **3** or are used to track and demodulate a received signal as in FIG. **4**.

The embodiments described herein may substantially reduce interference caused by unwanted signals and improve signal processing. For example, poor signal quality due to interference may deleteriously affect acquisition, tracking and demodulation of selected signals. A reduction of interference may, therefore, result in improved signal processing and error reduction. In regards to such benefits, the embodiments herein may advantageously require use within a CDMA telephony system. Improved processing within a CDMA telephony system may be exploited in terms of increased system capacity, transmit power reduction, system coverage and/or data rates. However, those skilled in the art should readily recognize that the above embodiments should not be limited to any particular method of signaling. For example, the embodiments disclosed herein may also be advantageous to systems employing CDMA (e.g., such as cdmaOne and cdma2000), WCDMA, Broadband CDMA and GPS signals.

Additionally, it should be noted that the above embodiments of the invention may be implemented in a variety of ways. For example, the above embodiments may be implemented from software, firmware, hardware or various combinations thereof. Those skilled in the art are familiar with software, firmware, hardware and their various combinations. To illustrate, those skilled in the art may choose to implement aspects of the invention in hardware using ASIC chips, Digital Signal Processors ("DSP") and/or other integrated circuitry (e.g., custom designed circuitry and Xilinx chips). Alternatively, aspects of the invention may be implemented through combinations of software using Java, C, C++, Matlab, and/or processor specific machine and assembly languages. Accordingly, those skilled in the art should readily recognize that such implementations are a matter of design choice and that the invention should not be limited to any particular implementation.

While the invention has been illustrated and described in detail in the drawings and foregoing description, such illustration and description is to be considered as exemplary and not restrictive in character. Accordingly, it should be understood that only the preferred embodiment and minor variants thereof have been shown and described and that all changes and modifications that come within the spirit of the invention are desired to be protected.

What is claimed is:

1. A processing engine, comprising:

a plurality of matrix generators, wherein each of the plurality of matrix generators is configured for generating a matrix comprising elements representing components of a code of a different one of a plurality of interfering signals selected for suppression;

a processor communicatively coupled to the plurality of matrix generators and configured for generating a plurality of suppression operators;

a plurality of applicators, wherein each applicator is communicatively coupled to the processor and configured for applying at least one of the plurality of suppression operators to an input signal to substantially suppress at least one of the plurality of interfering signals; and

an interference selector configured for selecting at least one of the plurality of interfering signals as an input to the plurality of matrix generators, wherein the interference selector selects at least one of the plurality of interfering signals based on a pre-determined criteria including at least one of amplitude, timing offset, phase, or code sequence;

wherein the processing engine is in a receiver and wherein the processing engine further comprises a connection element configured for receiving one or more output signals from the plurality of applicators and for selecting one or more of the one or more output signals as inputs to one or more processing fingers of the receiver;

wherein the connection element comprises one or more selectors configured for receiving one or more of the output signals and for selecting one or more of the output signals as inputs to one or more of the processing fingers;

wherein the output signals are interference suppressed signals; and

wherein the plurality of matrix generators are in parallel with each other.

2. The processing engine of claim **1**, wherein at least one of the one or more selectors is further configured for receiving a digitized signal comprising one or more Code Division Multiple Access signals as an input to one of the processing fingers.

3. The processing engine of claim **1**, wherein at least one of the one or more selectors is further configured for receiving a digitized signal comprising one or more Wideband Code Division Multiple Access signals as an input to one of the processing fingers.

4. The processing engine of claim **1**, wherein each of the one or more selectors is further configured for receiving a digitized signal comprising one or more Global Positioning System signals as an input to one of the processing fingers.

5. The processing engine of claim **1**, wherein the interference selector is further configured for providing on-time interfering pseudo noise (PN) codes of the interfering signals to the plurality of matrix generators.

6. The processing engine of claim **1**, wherein the interference selector selects the at least one of the plurality of interfering signals based on amplitude.

7. The processing engine of claim **1**, wherein the interference selector selects the at least one of the plurality of interfering signals based on timing offset.

8. The processing engine of claim **1**, wherein the interference selector selects the at least one of the plurality of interfering signals based on phase.

9. The processing engine of claim **1**, wherein the interference selector selects the at least one of the plurality of interfering signals based on code sequence.

10. A method of suppressing interference, comprising:

generating a plurality of matrices, each of the plurality of matrices comprising elements of a different one of a plurality of interference signals selected for suppression;

generating a plurality of suppression operators from the plurality of matrices;

applying the plurality of suppression operators in parallel to an input signal to substantially suppress at least one of the interference signals;

selecting one or more output signals generated in response to applying, for assignment of the one or more output signals to one or more processing fingers of a receiver;

selecting at least one of the plurality of interference signals for input to the plurality of matrices, wherein the at least one of the plurality of interference signals is selected based on a pre-determined criteria including at least one of amplitude, timing offset, phase, or code sequence;

wherein the one or more output signals are interference suppressed signals; and

wherein the plurality of matrices are in parallel with each other.

11. The method of claim **10**, further comprising providing one or more on-time interfering pseudo noise (PN) codes of the interfering signals to the matrices in response to selecting.

12. The method of claim **10**, further comprising transferring the one or more output signals to the one or more processing fingers in response to selecting said output signals as input signals to the processing fingers.

13. The method of claim **10**, further comprising receiving a Code Division Multiple Access signal.

14. The method of claim **10**, further comprising receiving a Wideband Code Division Multiple Access signal.

15. The method of claim **10**, further comprising receiving a Global Positioning System signal.

16. The method of claim **10**, wherein the at least one of the plurality of interference signals is selected based on amplitude.

17. The method of claim **10**, wherein the at least one of the plurality of interference signals is selected based on timing offset.

18. The method of claim **10**, wherein the at least one of the plurality of interference signals is selected based on phase.

19. The method of claim **10**, wherein the at least one of the plurality of interference signals is selected based on code sequence.

20. A system for suppressing interference, comprising:

means for generating a plurality of matrices, each matrix comprising elements of a different one of a plurality of interference signals selected for suppression;

means for generating a plurality of suppression operators from the plurality of matrices;

means for applying the plurality of suppression operators in parallel to an input signal to substantially suppress at least one of the plurality interference signals to form one or more output signals; and

means for selecting at least one of the plurality of interfering signals as inputs to the plurality of matrices, wherein the at least one of the plurality of interfering signals is selected based on a pre-determined criteria including at least one of amplitude, timing offset, phase, or code sequence; and

wherein the plurality of matrices are in parallel with each other.

21. The system of claim **20**, further comprising means for providing on-time interfering pseudo noise (PN) codes of one or more of the plurality of interfering signals to the one or more matrices in response to selecting.

22. The system of claim **21**, further comprising means for receiving a Wideband Code Division Multiple Access signal.

23. The system of claim **20**, further comprising means for selecting the one or more output signals for assignment of the one or more output signals to one or more processing fingers of a receiver.

24. The system of claim **23**, further comprising means for transferring one or more output signals to the one or more processing fingers in response to selecting said output signals.

25. The system of claim **23**, wherein the one or more output signals are interference suppressed signals.

26. The system of claim **20**, further comprising means for receiving a Code Division Multiple Access signal.

27. The system of claim **20**, further comprising means for receiving a Global Positioning System signal.

28. The system of claim **20**, wherein the at least one of the plurality of interfering signals is selected based on amplitude.

29. The system of claim **20**, wherein the at least one of the plurality of interfering signals is selected based on timing offset.

30. The system of claim **20**, wherein the at least one of the plurality of interfering signals is selected based on phase.

31. The system of claim **20**, wherein the at least one of the plurality of interfering signals is selected based on code sequence.

32. A mobile handset, comprising:

a receiver configured for receiving a signal;

a processing engine communicatively coupled to the receiver and comprising

a plurality of matrix generators, wherein each of the plurality of matrix generators is configured for generating a matrix comprising elements of a different one of a plurality of interfering signals selected for suppression;

a processor communicatively coupled to the plurality of matrix generators and configured for generating a plurality of suppression operators;

a plurality of applicators, wherein each of the plurality of applicators is communicatively coupled to the processor and configured for applying at least one of the plurality of suppression operators to an input signal to substantially suppress at least one of the plurality of interfering signals; and

an interference selector configured to select at least one of the plurality of interfering signals as inputs to the plurality of matrix generators, wherein the at least one of the plurality of interfering signals is selected based on a pre-determined criteria including at least one of amplitude, timing offset, phase, or code sequence;

wherein the plurality of matrix generators are in parallel with each other.

33. The mobile handset of claim **32**, wherein the processing engine further comprises a connection element configured for receiving output signals from the plurality of applicators and for selecting one or more output signals as inputs to one or more processing fingers of the receiver.

34. The mobile handset of claim **33**, wherein the connection element comprises one or more selectors configured for receiving one or more output signals and for selecting one or more of the one or more output signals as inputs to one or more of the processing fingers.

35. The mobile handset of claim **34**, wherein one or more of the one or more selectors is further configured for receiving a digitized signal comprising one or more Code Division Multiple Access signals as one of the inputs to one of the processing fingers.

36. The mobile handset of claim **34**, wherein one or more of the one or more selectors is further configured for receiving a digitized signal comprising one or more Wideband Code Division Multiple Access signals as one of the inputs to one of the processing fingers.

37. The mobile handset of claim **34**, wherein one or more of the one or more selectors is further configured for receiving a digitized signal comprising one or more Global Positioning System signals as one of the inputs to one of the processing fingers.

38. The mobile handset of claim **33**, wherein the output signals are interference suppressed signals.

39. The mobile handset of claim **32**, wherein the interference selector is further configured for providing on-time interfering pseudo noise (PN) codes of the plurality of interfering signals to the plurality of matrix generators.

40. The mobile handset of claim **32**, wherein the signal comprises a Code Division Multiple Access signal.

41. The mobile handset of claim **32**, wherein the signal comprises a Wideband Code Division Multiple Access signal.

42. The mobile handset of claim **32**, wherein the signal comprises a Global Positioning System signal.

43. The mobile handset of claim **32**, wherein the at least one of the plurality of interfering signals is selected based on amplitude.

44. The mobile handset of claim **32**, wherein the at least one of the plurality of interfering signals is selected based on timing offset.

45. The mobile handset of claim **32**, wherein the at least one of the plurality of interfering signals is selected based on phase.

46. The mobile handset of claim **32**, wherein the at least one of the plurality of interfering signals is selected based on code sequence.

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