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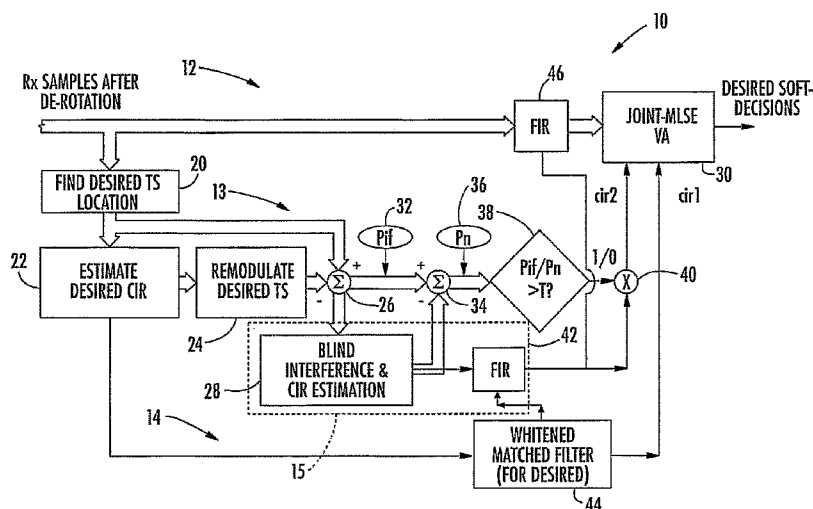
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(54) Title: WIRELESS COMMUNICATIONS DEVICE INCLUDING A JOINT DEMODULATION FILTER FOR CO-CHANNEL INTERFERENCE REDUCTION AND RELATED METHODS



(S7) Abstract: A wireless communications device may include a housing and a wireless transmitter and a wireless receiver carried by the housing. The wireless receiver may include a joint demodulation filter for reducing co-channel interference between a desired signal and a co-channel interfering signal which may include an input receiving samples of the desired signal and the co-channel interfering signal, a Viterbi decoder, and a first signal path between the input and the Viterbi decoder comprising a first filter. The joint demodulation filter may further include a second signal path between the input and the Viterbi decoder and comprising a linear finite impulse response (FIR) modeler for generating a channel impulse response estimate for the co-channel interfering signal. Additionally, a third signal path may be between the input and the Viterbi decoder and include a whitened matched filter for generating a channel impulse response estimate for the desired signal.

**WIRELESS COMMUNICATIONS DEVICE INCLUDING A JOINT
DEMODULATION FILTER FOR CO-CHANNEL INTERFERENCE
REDUCTION AND RELATED METHODS**

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Field of the Invention

The present invention relates to wireless communications systems, such as cellular communications systems, and, more particularly, to filtering received wireless signals to reduce unwanted interference.

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Background

Cellular communications systems continue to grow in popularity and have become an integral part of both personal and business communications. Cellular telephones allow users to place and receive voice calls most anywhere they travel. However, with ever increasing numbers of cellular phone users comes greater challenges for wireless communications device and network providers. One such challenge is addressing interference caused between multiple cellular devices operating in a given geographical area. Cellular devices communicate with a cellular base station using common or shared wireless communications channels (i.e., frequencies). Yet, in some cases signals between other devices and a base station using the same channel may cause a desired signal from the base station to be significantly degraded or even dropped by the handheld device. Such interference is called co-channel interference.

Because of the increasing load on cellular communications infrastructures, various single-antenna interference cancellation (SAIC) approaches have been investigated to meet requirements for Downlink Advanced Receiver Performance (DARF). This effort is being standardized by the third generation mobile communications system and the Third Generation Partnership Project (3GPP).

One SAIC technique that has been investigated is based upon joint demodulation of the desired and interfering sequences. Generally speaking, this approach begins with a standard least-squares (LS) estimate of the propagation channel and a static channel profile for the interferer. Then, a modified Viterbi decoder is used in which half of the state bits represent the user sequence and the other half represent the interferer. A joint branch metric is minimized and the estimated sequences for the desired and interfering

signal are used in a least mean squares (LMS) algorithm to update the channel estimates for both the desired and interfering propagation channel.

The 3GPP initiative has given consideration to the application of joint demodulation in synchronized wireless networks. See, e.g., "Feasibility Study on Single Antenna Interference Cancellation (SAIC) for GSM Networks," 3GPP TR 45.903 Version 6.0.1, Release 6, European Telecommunications Standards Institute, 2004. This is the more limited case that requires one to assume that the base station synchronization data sequences (i.e., training sequences) of the desired-signal and dominant-interferer overlap, which in turn makes the estimation of the CIRs possible using previously known techniques. It also requires one to assume that the interferer will be dominant for the entire burst.

However, in asynchronous network applications the training sequences of interfering signals may not overlap those of the desired signal, which makes CIR estimation problematic. Accordingly, further developments may be desirable to make joint demodulation techniques practical to implement in both synchronous and asynchronous networks.

Brief Description of the Drawings

FIG. 1 is a schematic block diagram of an exemplary Single Antenna Interference Cancellation (SAIC) enabled joint demodulation Global System for Mobile Communication (GSM) receiver in accordance with the present invention.

FIG. 2 is a schematic block diagram of an exemplary embodiment of the joint demodulation receiver of FIG. 1 shown in greater detail.

FIG. 3 is a graph of simulated performance results for an SAIC joint demodulation receiver in accordance with the present invention and a typical GMSK receiver in accordance with the prior art.

FIG. 4 is a flow diagram of an exemplary joint demodulation filtering method for reducing co-channel interference between a desired signal and a co-channel interfering signal in accordance with the invention.

FIG. 5 is a schematic block diagram of an exemplary wireless communication device in which the joint demodulation receiver of FIG. 1 may be used.

Detailed Description of the Preferred Embodiments

The present description is made with reference to the accompanying drawings, in which preferred embodiments are shown. However, many different embodiments may be used, and thus the description should not be construed as limited to the embodiments set forth herein. Rather, these embodiments are provided so that this disclosure will be
5 thorough and complete. Like numbers refer to like elements throughout.

Generally speaking, a wireless communications device including a housing and a wireless transmitter and a wireless receiver carried by the housing is described herein. In particular, the wireless receiver may include a joint demodulation filter for reducing co-channel interference between a desired signal and a co-channel interfering signal. The
10 joint demodulation filter may include an input receiving samples of the desired signal and the co-channel interfering signal, a Viterbi decoder, and a first signal path between the input and the Viterbi decoder comprising a first filter. The joint demodulation filter may further include a second signal path between the input and the Viterbi decoder and
15 comprising a linear finite impulse response (FIR) modeler for generating a channel impulse response estimate for the co-channel interfering signal. Additionally, a third signal path may be between the input and the Viterbi decoder and include a whitened matched filter for generating a channel impulse response estimate for the desired signal.

More particularly, the desired signal and the co-channel interfering signal may
20 each include a training sequence, and the joint demodulation filter may further include a training-sequence locator upstream of the second and third paths and downstream from the input. Additionally, the third signal path may include a desired-signal channel impulse response (CIR) estimator upstream of the whitened matched filter for generating a desired-signal CIR estimate. Furthermore, the first filter may be a first finite impulse response
25 (FIR) filter.

The second signal path may include a first summer and a second summer connected downstream therefrom. Moreover, the second signal path may further include a remodulator between the desired-signal CIR estimator and the first summer and cooperating therewith for subtracting a remodulated desired-signal training sequence from
30 samples of the desired signal and the co-channel interfering signal to thereby generate an interference signal estimate. In addition, the linear FIR modeler may include a blind interference and CIR estimator, and a second FIR filter downstream from the blind

interference and CIR estimator. The Viterbi decoder may also iteratively build a tree of interferer bit sequence hypotheses.

A joint demodulation filtering method for reducing co-channel interference between a desired signal and a co-channel interfering signal in a wireless communications receiver may include filtering receiving samples of the desired signal and the co-channel interfering signal using a first signal path comprising a first filter. The method may further include generating a channel impulse response estimate for the co-channel interfering signal using a second signal path comprising a linear finite impulse response (FIR) modeler, and generating a channel impulse response estimate for the desired signal using a third signal path comprising a whitened matched filter. In addition, a decoding operation may be performed based upon the filtered received samples of the desired signal and the co-channel interfering signal, the channel impulse response estimate for the co-channel interfering signal, and the channel impulse response estimate for the desired signal using a Viterbi decoder.

Turning first to FIGS. 1 and 2, a joint demodulation filter **10** in accordance with an exemplary embodiment illustratively includes an input **11** receiving samples of a desired signal and a co-channel interfering signal, e.g., from the antenna of a wireless communications device (e.g., a mobile cellular device). That is, the joint demodulation filter **10** may advantageously be implemented in a wireless receiver of a mobile wireless communications device. The various components of the joint demodulation filter **10** may be implemented using software modules and a processing circuitry, such as a digital signal processor (DSP), for example, although other implementations are also possible, as will be appreciated by those skilled in the art. Exemplary components of a mobile cellular device in which the joint demodulation filter **10** may be used will be discussed further below with reference to FIG. 5.

The joint demodulation filter **10** further illustratively includes a Viterbi decoder **30**, and a first signal path **12** between the input **11** and the Viterbi decoder comprising a first filter **46**. In the exemplary embodiment shown in FIG. 2, the first filter **46** may be a finite infinite response (FIR) filter, such as a matched filter, for example. Also, a second signal path **13** is included between the input **11** and the Viterbi decoder **30**. The second signal path **13** illustratively includes a linear FIR modeler **15** for generating a channel impulse response estimate for the co-channel interfering signal. Additionally, a third signal path **14** is illustratively connected between the input **11** and the Viterbi decoder **30**. The third

signal branch illustratively includes a whitened matched filter **44** for generating a channel impulse response estimate for the desired signal, as will be discussed further below.

Additional components of the exemplary joint demodulation filter **10** illustrated in FIG. 2 will now be briefly identified, followed by a description of the various functions thereof. As noted above, in a cellular communications GSM-based network, for example, a desired signal and a co-channel interfering signal will each include a training sequence. The joint demodulation filter **10** illustratively includes a training-sequence locator **20** for the desired signal upstream of the second and third paths **13**, **14** and downstream from the input **11**. The third signal path **14** illustratively includes a desired-signal CIR estimator **22** upstream of the whitened matched filter **44** for generating a desired-signal CIR estimate.

The second signal path **13** also illustratively includes a first summer **26**, a second summer **34** connected downstream from the first summer, and a remodulator **24** between the desired-signal CIR estimator **22** and the first summer and cooperating therewith for subtracting a remodulated desired-signal training sequence from samples of the desired signal and the co-channel interfering signal to thereby generate an interference signal estimate. The linear FIR modeler **15** illustratively includes a blind interference and CIR estimator **28**, coupled to the summer **26**, and a second FIR filter **42** downstream from the blind interference and CIR estimator **28**, which also receives an input from the whitened matched filter **44**. The second summer **34** also receives an output of the blind interference and CIR estimator **28**, as shown.

The second signal path **13** further illustratively includes a residual noise power (P_n) sample offset block **32** between the first and second summers **26**, **34**, a significant interferer component (P_{if}) sample offset block downstream from the second summer, and a P_{if}/P_n decision block **38** downstream from the P_{if} sample offset block, as will be discussed further below. A mixer **40** is downstream from the P_{if} sample offset block **38** and also receives an output of the second FIR filter **42** as shown. The output of the mixer **40** and the output of the whitened matched filter **44** are provided to the Viterbi decoder **30**, as is the output of the first FIR **46**.

The operation of the joint demodulation receiver **10** will now be described in further detail. As noted above, the joint demodulation (JD) receiver **10** may advantageously be used in wireless communications systems, such as in cellular base stations and mobile cellular communications devices, for example. Generally speaking, joint demodulation uses estimates for a channel impulse response (CIR) for a desired

signal and a dominant interferer associated therewith. For a GSM implementation, which will be discussed below, it will be assumed that the dominant interferer is a GMSK modulated signal conforming to the GSM specification.

The joint demodulation approach set forth herein may be applicable to both
5 synchronized and unsynchronized networks, in that this technique uses “blind” interferer data and channel estimation techniques rather than making the above-noted assumptions. Once the CIRs have been estimated, a two-dimensional (joint) adaptive Viterbi state structure may be used in the equalizer to estimate the data for both the desired signal and the interferer.

10 Simulations of the present joint demodulation technique have demonstrated greater than 10 dB carrier-to-interference(C/I) improvement at about 0 dB C/I in the raw symbol error rate and frame error rate for 12.2-rate AMR FS speech. In the simulations, a new joint-least-squares based technique was used for channel-offset positioning and desired and interferer CIR estimation. As noted above, this approach is coupled with blind
15 estimation of the interferer data (i.e., with no a-priori knowledge of the interferer’s data).

The present joint demodulation approach may be particularly advantageous in its ability to provide relatively high gains (i.e., in its ability to receive at very low signal-to-noise ratios (SNRs)) when limited a-priori knowledge about the interferer is available, as will be discussed further below. Yet, the Viterbi algorithm (VA) complexity may also
20 increase, (depending on the number of states used to model the interferer), thus the processing requirements and the additional complexity of the channel/data estimators may be a factor in some software or hardware implementations.

For the test configuration, a system level Block Error Rate (BLER) simulator was extended to support all of the interferer models/scenarios being used by the 3GPP DARP
25 work group. This extension also allows new interferer models to be developed as needed. The simulations were performed using Matlab.

The joint demodulation approach assumes that the dominant interference component may be modeled as the noisy output of a finite-impulse-response (FIR) (unknown) filter with unknown, binary, random input (interferer) data. In the case of a
30 dominant GMSK-modulated interferer, this assumption holds even if there are additional, weaker interference signals present, which are treated as residual noise. Moreover, this approach may be applied to other interferer modulation types using the above modeling assumption.

Referring again to FIG. 2, the steps associated with the joint demodulation approach are as follows. First, a base station training sequence (TS) for the desired signal is found (Block 20), the CIR for the desired signal is estimated (Block 22), and the re-modulated desired training sequence is removed from the input samples to form the interferer-signal estimate (Block 24). Furthermore, the “blind” estimation of the interferer CIR and data is performed based upon the interferer-signal estimate, at Blocks 26, 28. Next, a joint least-squares desired/interferer channel estimation using the desired training sequence and estimated interferer data is performed at Block 30, as will be discussed further below.

In addition, the foregoing steps may be repeated (or performed in a vectorized form) at multiple input sample offsets (as the timing offset varies). As such, the offset yielding the minimal residual noise power (P_n) may be selected, and a determination may be made as to whether the model applies (i.e., was a significant interferer component (P_{if}) detected or not), at Blocks 32, 34, 36, and 38. If so, demodulation is performed using a joint-demodulation (multi-dimensional state) Viterbi algorithm that estimates and removes the interference jointly with the estimation of the desired-signal data (Block 30).

Initially, the desired channel impulse response was estimated using a conventional training-sequence correlation (i.e., “channel-sounding”) method, as will be appreciated by those skilled in the art. At low C/I levels, the least-squares method provides the initial desired channel impulse response estimate by multiplying the input samples by a constant (pre-computed) matrix $(A^H A)^{-1} A^H$, where A is the training-sequence convolution matrix of the desired signal.

For estimating the interferer, the above-noted SAIC Feasibility Study assumes a synchronous network model. More particularly, this model assumes that the training sequence of the interfering signal is aligned with the desired signal’s training sequence within a -1 to +4 symbol offset. In this case, the interferer channel impulse response can be estimated using the training-sequence correlation technique (or least squares, since the training-sequence data is known) after removing the desired signal’s (re-modulated) training sequence from the received samples.

However, to widen the potential applicability of the joint-demodulation approach to the asynchronous network case where the interferer data during the desired signal’s training sequence is unknown, blind channel and data estimation and demodulation techniques are used. By way of background in this regard, reference is made to the article

by Seshadri entitled "Joint Data and Channel Estimation Using Blind Trellis Search Techniques," IEEE Trans. on Communications, vol. 42, no. 2/3/4, pgs. 1000–1011, and the article by Daneshgaran et al. entitled "Blind Estimation of Output Labels of SIMO Channels Based on a Novel Clustering Algorithm," IEEE Communications Letters, vol. 2, no. 11, November 1998, pgs. 307-309.

One particular difficulty of performing blind interferer estimation is the very small number of "observable" interferer (i.e., noisy) samples during the desired signal's training-sequence window. By way of reference, the sequence window is the length of the desired training sequence (for this embodiment, the training sequence length is 26, as defined by the GSM 05-series standards) less the desired signal's CIR length (5 is chosen by this simulation, however other values between 1 and 7 are possible depending on the channel models as defined by the GSM standards) plus one, or: $26 - 5 + 1 = 22$ (twenty-two) in the present example.

This approach uses an algorithm which combines concepts of vector quantization and sequential decoding of convolutional codes. The algorithm is based on two assumptions: (1) the interferer signal may be modeled with a linear Finite Impulse Response (FIR) source (Block 28); and (2) the interferer signal is corrupted by residual additive white (i.e., uncorrelated) Gaussian noise (after removing the estimated desired signal) (FIG. 1, 26).

With these two assumptions, the algorithm iteratively builds a tree of interferer bit sequence hypotheses. For each new bit added to a bit sequence hypothesis, it computes the new FIR state (or codebook index, as will be apparent to those skilled in the art of vector quantization) and averages all input samples corresponding to the same state in a particular sequence to estimate the FIR output (codebook value) for that state. The distortion of a bit sequence is what remains after removing the sequence's FIR outputs from the input samples (FIG. 2, 36). After keeping up to W (search width parameter) bit sequences with the lowest distortions, each sequence is extended by another 0/1 bit to yield two new sequences ($2W$ total), and the process of re-estimating FIR outputs of each sequence is repeated followed by keeping the W sequences with minimum distortion (e.g., one-half the sequences). When the sequence length reaches the number of interferer-signal samples available (22 for this embodiment, as described above), the sequence with the lowest distortion out of W candidates is chosen.

This above-described algorithm provides the initial interferer data and channel impulse response estimates for subsequent joint least-squares desired-signal and interferer-channel estimation. At C/I levels below 5dB, the CIR position (offset), and CIR value estimation for the desired and interferer is affected by the cross-correlation of the desired and interferer data sequences. However, using the previously obtained interferer data estimate, a joint least-squares channel estimation is possible that removes (i.e., accounts for) this cross-correlation as follows:

$$\begin{bmatrix} A' \\ B' \end{bmatrix} s = \begin{bmatrix} A' A & B' A \\ A' B & B' B \end{bmatrix} \begin{bmatrix} h \\ g \end{bmatrix},$$

where s contains the input samples during the desired training-sequence window (26-5+1=22 as described previously), A ($N \times L_h$) and B ($N \times L_g$) are the desired-signal and interferer data-sequence convolution matrices (A is known and constant, B is an estimate for the interferer), and h and g are the desired-signal and interferer CIRs respectively that result from solving the above equations with L_h (5 in this embodiment) the length of h , and L_g (3 chosen for this embodiment) the length of g .

Once estimates of the desired and interferer channel impulse responses are available, a two-dimensional state Viterbi algorithm may be applied. For a Euclidean distance metric, the whitened discrete time model filter (WMF) is computed from the estimated desired CIR (Block 44). The computation is also applied to the interferer CIR, and the three (L_g) largest resulting taps are used to form the interferer codebook (i.e., a set of possible interferer channel FIR outputs). Of course, other numbers of taps L_h and L_g may also be used in some embodiments.

The resulting desired-signal and interferer codebooks are passed to the joint-demodulation Viterbi algorithm. The returned soft-decision metrics include the forward and backward recursion using the difference of the odd/even state minimum metrics at each stage (not path) as the soft decision value and sign.

Turning now to FIG. 3, simulated results for TCH-AFS 12.2 rate speech for a typical urban fading profile at 50km vehicle speeds (TU-50) at the 1950MHz band without the use of frequency hopping and using interferer model DTS1 are shown, as will be appreciated by those skilled in the art. C/I is the average carrier-to-interference ratio.

The dotted lines **50** and **51** represent the SER (symbol error rate) and FER (frame error rates) of the conventional GMSK receiver. The dashed lines **53** and **54** represent the performance of the above-described SAIC-JD receiver. The solid lines **55** and **56** represent the performance of a higher-complexity SAIC-JD receiver in accordance with an exemplary embodiment of the invention in which the blind vector quantization of the interferer is performed using recursive least squares (RLS) updates while the interferer symbol sequence hypotheses are formed and evaluated. As will be appreciated by those skilled in the art, the performance plot demonstrates that both of the SAIC-JD receivers provide significant improvement over the conventional receiver in a high interference environment.

The amount of residual “noise” power remaining in the desired signal's training-sequence window after removing the desired (i.e., estimated) samples may be used as a test of model “fit” in some embodiments. If removing the subsequently estimated interferer does not reduce the residual power significantly, a non-interference signal model may be selected, and vice-versa.

A joint demodulation filtering method for reducing co-channel interference between a desired signal and a co-channel interfering signal will now be described with reference to FIG. 4. Beginning at Block **60**, receiving samples of the desired signal and the co-channel interfering signal are filtered using a first signal path **12** comprising a first filter **46**, at Block **61**. The method may further include generating a channel impulse response estimate for the co-channel interfering signal using a second signal path **13** comprising a linear finite impulse response (FIR) modeler **15**, at Block **62**, and generating a channel impulse response estimate for the desired signal using a third signal path **14** comprising a whitened matched filter **44**, at Block **63**. In addition, a decoding operation may be performed based upon the filtered received samples of the desired signal and the co-channel interfering signal, the channel impulse response estimate for the co-channel interfering signal, and the channel impulse response estimate for the desired signal using a Viterbi decoder **30**, at Block **64**, thus concluding the illustrated method (Block **65**).

One example of a hand-held mobile wireless communications device **1000** that may be used in accordance with the system **20** is further described in the example below with reference to FIG. 5. The device **1000** illustratively includes a housing **1200**, a keypad **1400** and an output device **1600**. The output device shown is a display **1600**, which is preferably a full graphic LCD. Other types of output devices may alternatively be utilized.

A processing device **1800** is contained within the housing **1200** and is coupled between the keypad **1400** and the display **1600**. The processing device **1800** controls the operation of the display **1600**, as well as the overall operation of the mobile device **1000**, in response to actuation of keys on the keypad **1400** by the user.

5 The housing **1200** may be elongated vertically, or may take on other sizes and shapes (including clamshell housing structures). The keypad may include a mode selection key, or other hardware or software for switching between text entry and telephony entry.

 In addition to the processing device **1800**, other parts of the mobile device **1000** are shown schematically in FIG. 5. These include a communications subsystem **1001**; a short-
10 range communications subsystem **1020**; the keypad **1400** and the display **1600**, along with other input/output devices **1060**, **1080**, **1100** and **1120**; as well as memory devices **1160**, **1180** and various other device subsystems **1201**. The mobile device **1000** is preferably a two-way RF communications device having voice and data communications capabilities. In addition, the mobile device **1000** preferably has the capability to communicate with
15 other computer systems via the Internet.

 Operating system software executed by the processing device **1800** is preferably stored in a persistent store, such as the flash memory **1160**, but may be stored in other types of memory devices, such as a read only memory (ROM) or similar storage element. In addition, system software, specific device applications, or parts thereof, may be
20 temporarily loaded into a volatile store, such as the random access memory (RAM) **1180**. Communications signals received by the mobile device may also be stored in the RAM **1180**.

 The processing device **1800**, in addition to its operating system functions, enables execution of software applications **1300A-1300N** on the device **1000**. A predetermined set
25 of applications that control basic device operations, such as data and voice communications **1300A** and **1300B**, may be installed on the device **1000** during manufacture. In addition, a personal information manager (PIM) application may be installed during manufacture. The PIM is preferably capable of organizing and managing data items, such as e-mail, calendar events, voice mails, appointments, and task items. The
30 PIM application is also preferably capable of sending and receiving data items via a wireless network **1401**. Preferably, the PIM data items are seamlessly integrated, synchronized and updated via the wireless network **1401** with the device user's corresponding data items stored or associated with a host computer system.

Communication functions, including data and voice communications, are performed through the communications subsystem **1001**, and possibly through the short-range communications subsystem. The communications subsystem **1001** includes a receiver **1500**, a transmitter **1520**, and one or more antennas **1540** and **1560**. In addition, the communications subsystem **1001** also includes a processing module, such as a digital signal processor (DSP) **1580**, and local oscillators (LOs) **1601**. The specific design and implementation of the communications subsystem **1001** is dependent upon the communications network in which the mobile device **1000** is intended to operate. For example, a mobile device **1000** may include a communications subsystem **1001** designed to operate with the Mobitex™, Data TAC™ or General Packet Radio Service (GPRS) mobile data communications networks, and also designed to operate with any of a variety of voice communications networks, such as AMPS, TDMA, CDMA, WCDMA, PCS, GSM, EDGE, etc. Other types of data and voice networks, both separate and integrated, may also be utilized with the mobile device **1000**. The mobile device **1000** may also be compliant with other communications standards such as 3GSM, 3GPP, UMTS, etc.

Network access requirements vary depending upon the type of communication system. For example, in the Mobitex and DataTAC networks, mobile devices are registered on the network using a unique personal identification number or PIN associated with each device. In GPRS networks, however, network access is associated with a subscriber or user of a device. A GPRS device therefore requires a subscriber identity module, commonly referred to as a SIM card, in order to operate on a GPRS network.

When required network registration or activation procedures have been completed, the mobile device **1000** may send and receive communications signals over the communication network **1401**. Signals received from the communications network **1401** by the antenna **1540** are routed to the receiver **1500**, which provides for signal amplification, frequency down conversion, filtering, channel selection, etc., and may also provide analog to digital conversion. Analog-to-digital conversion of the received signal allows the DSP **1580** to perform more complex communications functions, such as demodulation and decoding. In a similar manner, signals to be transmitted to the network **1401** are processed (e.g. modulated and encoded) by the DSP **1580** and are then provided to the transmitter **1520** for digital to analog conversion, frequency up conversion, filtering, amplification and transmission to the communication network **1401** (or networks) via the antenna **1560**.

In addition to processing communications signals, the DSP **1580** provides for control of the receiver **1500** and the transmitter **1520**. For example, gains applied to communications signals in the receiver **1500** and transmitter **1520** may be adaptively controlled through automatic gain control algorithms implemented in the DSP **1580**.

5 In a data communications mode, a received signal, such as a text message or web page download, is processed by the communications subsystem **1001** and is input to the processing device **1800**. The received signal is then further processed by the processing device **1800** for an output to the display **1600**, or alternatively to some other auxiliary I/O device **1060**. A device user may also compose data items, such as e-mail messages, using
10 the keypad **1400** and/or some other auxiliary I/O device **1060**, such as a touchpad, a rocker switch, a thumb-wheel, or some other type of input device. The composed data items may then be transmitted over the communications network **1401** via the communications subsystem **1001**.

In a voice communications mode, overall operation of the device is substantially
15 similar to the data communications mode, except that received signals are output to a speaker **1100**, and signals for transmission are generated by a microphone **1120**. Alternative voice or audio I/O subsystems, such as a voice message recording subsystem, may also be implemented on the device **1000**. In addition, the display **1600** may also be utilized in voice communications mode, for example to display the identity of a calling
20 party, the duration of a voice call, or other voice call related information.

The short-range communications subsystem enables communication between the mobile device **1000** and other proximate systems or devices, which need not necessarily be similar devices. For example, the short-range communications subsystem may include an infrared device and associated circuits and components, or a Bluetooth™
25 communications module to provide for communication with similarly-enabled systems and devices.

Many modifications and other embodiments will come to the mind of one skilled in the art having the benefit of the teachings presented in the foregoing descriptions and the associated drawings. Therefore, it is understood that various modifications and
30 embodiments are intended to be included within the scope of the appended claims.

CLAIMS:

1. A wireless communications device comprising:

a housing; and

a wireless transmitter and a wireless receiver carried by said housing;

said wireless receiver comprising a joint demodulation filter for reducing co-channel interference between a desired signal and a co-channel interfering signal, the filter comprising

an input receiving samples of the desired signal and the co-channel interfering signal,

a Viterbi decoder,

a first signal path between said input and said Viterbi decoder comprising a first filter,

a second signal path between said input and said Viterbi decoder and comprising a linear finite impulse response (FIR) modeler for generating a channel impulse response estimate for the co-channel interfering signal, and

a third signal path between said input and said Viterbi decoder and comprising a whitened matched filter for generating a channel impulse response estimate for the desired signal.

2. The wireless communications device of Claim 1 wherein the desired signal and the co-channel interfering signal each includes a training sequence; and wherein said joint demodulation filter further comprises a training-sequence locator upstream of said second and third paths and downstream from said input.

3. The wireless communications device of Claim 1 wherein said third signal path comprises a desired-signal channel impulse response (CIR) estimator upstream of said whitened matched filter for generating a desired-signal CIR estimate.

4. The wireless communications device of Claim 1 wherein said first filter comprises a first finite impulse response (FIR) filter.

5. The wireless communications device of Claim 1 wherein said second signal path comprises a first summer and a second summer connected downstream therefrom.

6. The wireless communications device of Claim 5 wherein said second signal path further comprises a remodulator between said desired-signal CIR estimator and said first summer and cooperating therewith for subtracting a remodulated desired-signal training sequence from samples of the desired signal and the co-channel interfering signal to thereby generate an interference signal estimate.

7. The wireless communications device of Claim 1 wherein said linear FIR modeler comprises a blind interference and CIR estimator, and a second FIR filter downstream from said blind interference and CIR estimator.

8. The wireless communications device of Claim 1 wherein said wireless receiver comprises a cellular receiver.

9. A wireless communications device comprising:

a housing; and

a wireless transmitter and a wireless receiver carried by said housing;

said wireless receiver comprising a joint demodulation filter for reducing co-channel interference between a desired signal and a co-channel interfering signal where the desired signal and the co-channel interfering signal each includes a training sequence, the filter comprising

an input receiving samples of the desired signal and the co-channel interfering signal,

a Viterbi decoder,

a first signal path between said input and said Viterbi decoder comprising a first finite impulse response (FIR) filter,

a second signal path between said input and said Viterbi decoder and comprising a linear finite impulse response (FIR) modeler for generating a channel impulse response estimate for the co-channel interfering signal,

a third signal path between said input and said Viterbi decoder and comprising a whitened matched filter for generating a channel impulse response estimate for the desired signal, and

a training-sequence locator upstream of said second and third paths and downstream from said input.

10. The wireless communications device of Claim 9 wherein said third signal path comprises a desired-signal channel impulse response (CIR) estimator upstream of said whitened matched filter for generating a desired-signal CIR estimate.

11. The wireless communications device of Claim 9 wherein said second signal path comprises a first summer and a second summer connected downstream therefrom.

12. The wireless communications device of Claim 11 wherein said second signal path further comprises a remodulator between said desired-signal CIR estimator and said first summer and cooperating therewith for subtracting a remodulated desired-signal training sequence from samples of the desired signal and the co-channel interfering signal to thereby generate an interference signal estimate.

13. The wireless communications device of Claim 9 wherein said linear FIR modeler comprises a blind interference and CIR estimator, and a second FIR filter downstream from said blind interference and CIR estimator.

14. A method for reducing co-channel interference between a desired signal and a co-channel interfering signal in a receiver of a wireless communications device, the method comprising:

filtering received samples of the desired signal and the co-channel interfering signal using a first signal path comprising a first filter;

generating a channel impulse response estimate for the co-channel interfering signal using a second signal path comprising a linear finite impulse response (FIR) modeler;

generating a channel impulse response estimate for the desired signal using a third signal path comprising a whitened matched filter; and

performing a decoding operation based upon the filtered received samples of the desired signal and the co-channel interfering signal, the channel impulse response estimate for the co-channel interfering signal, and the channel impulse response estimate for the desired signal using a Viterbi decoder.

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15. The method of Claim 14 wherein the desired signal and the co-channel interfering signal each includes a training sequence; and further comprising performing a training-sequence location upstream of the second and third paths and downstream from the input.

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16. The method of Claim 14 wherein the third signal path comprises a desired-signal channel impulse response (CIR) estimator upstream of the whitened matched filter for generating a desired-signal CIR estimate.

15

17. The method of Claim 14 wherein the first filter comprises a first finite impulse response (FIR) filter.

18. The method of Claim 14 wherein the second signal path comprises a first summer and a second summer connected downstream therefrom.

20

19. The method of Claim 18 wherein the second signal path further comprises a remodulator between the desired-signal CIR estimator and the first summer and cooperating therewith for subtracting a remodulated desired-signal training sequence from samples of the desired signal and the co-channel interfering signal to thereby generate an interference signal estimate.

25

20. The method of Claim 14 wherein the linear FIR modeler comprises a blind interference and CIR estimator, and a second FIR filter downstream from the blind interference and CIR estimator.

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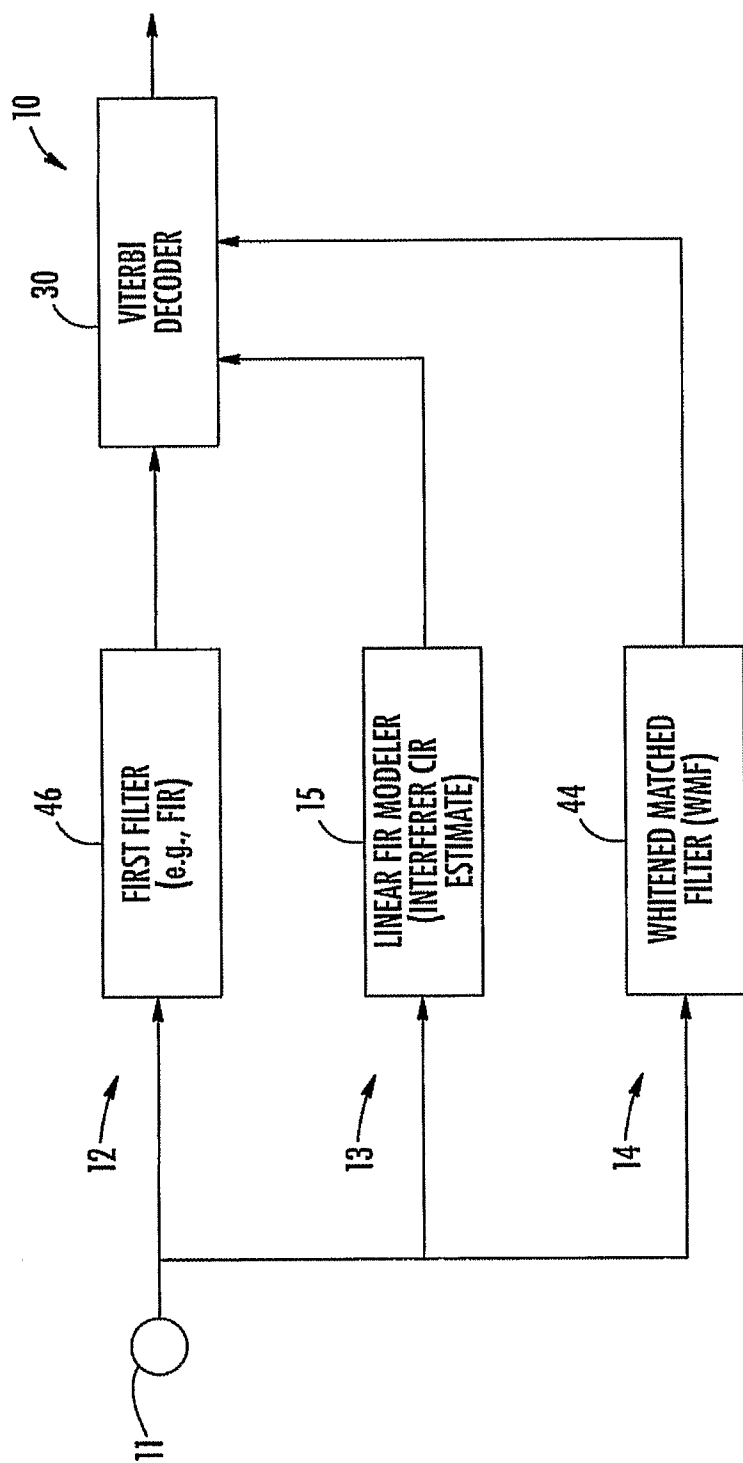
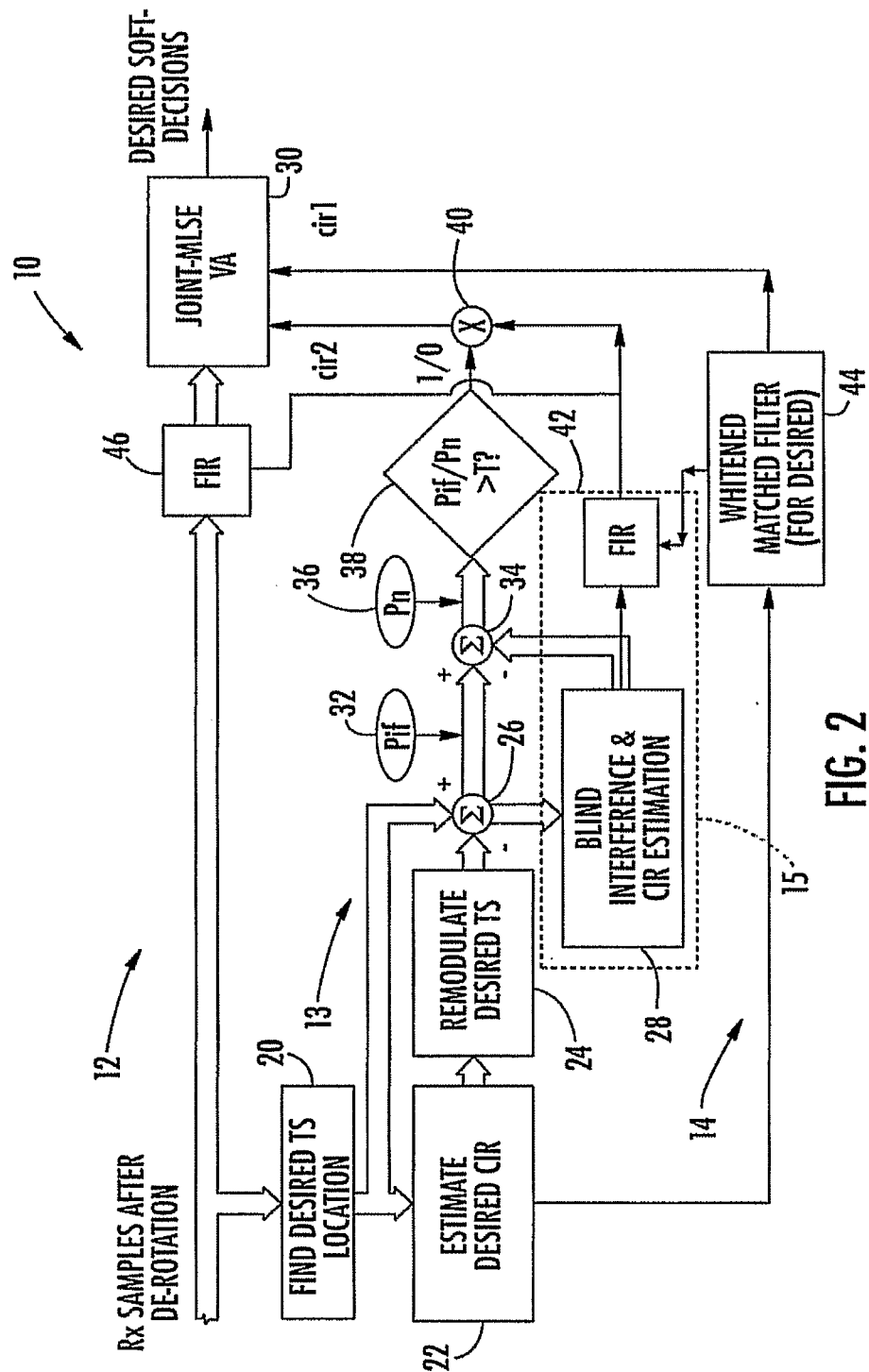
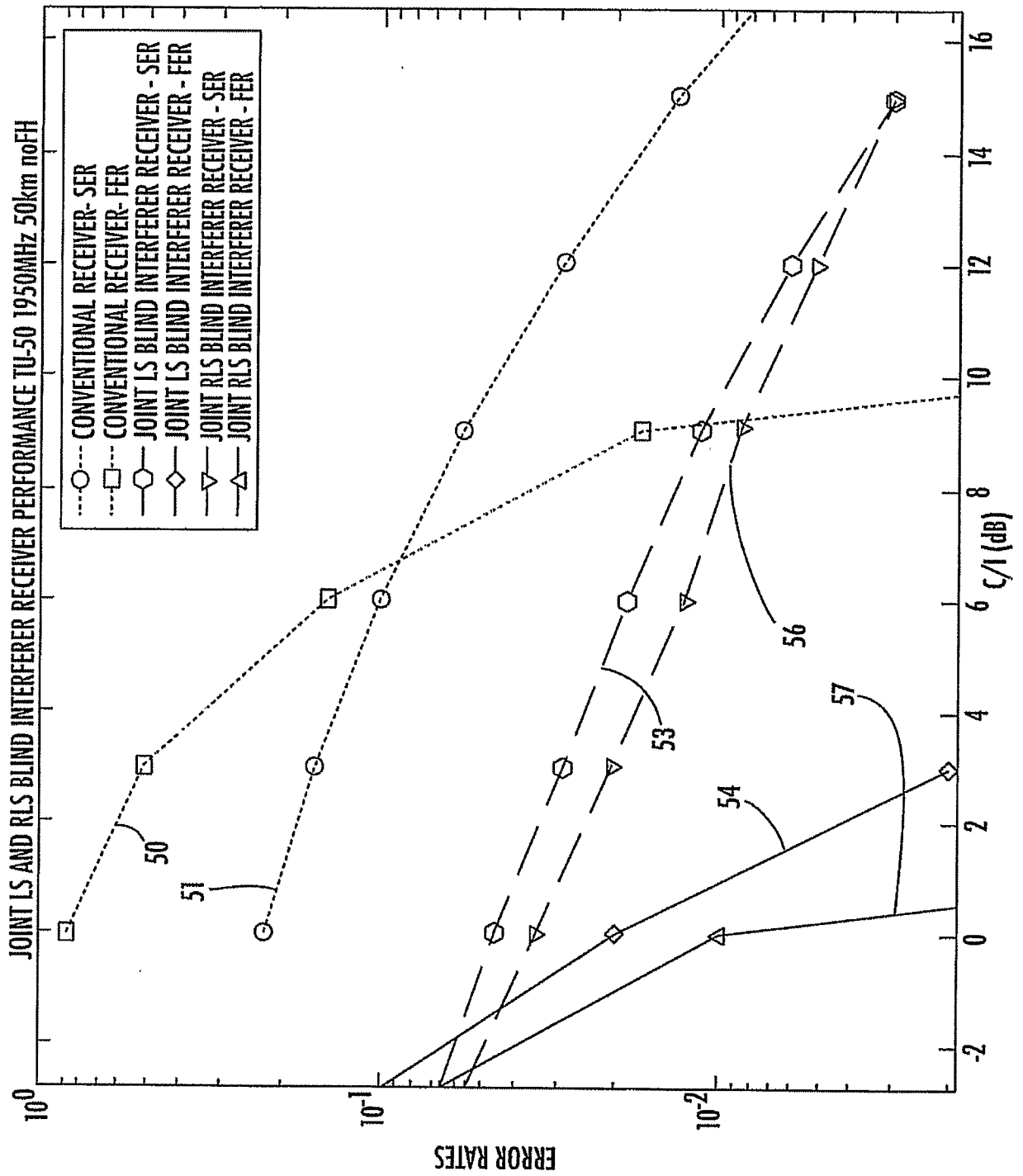
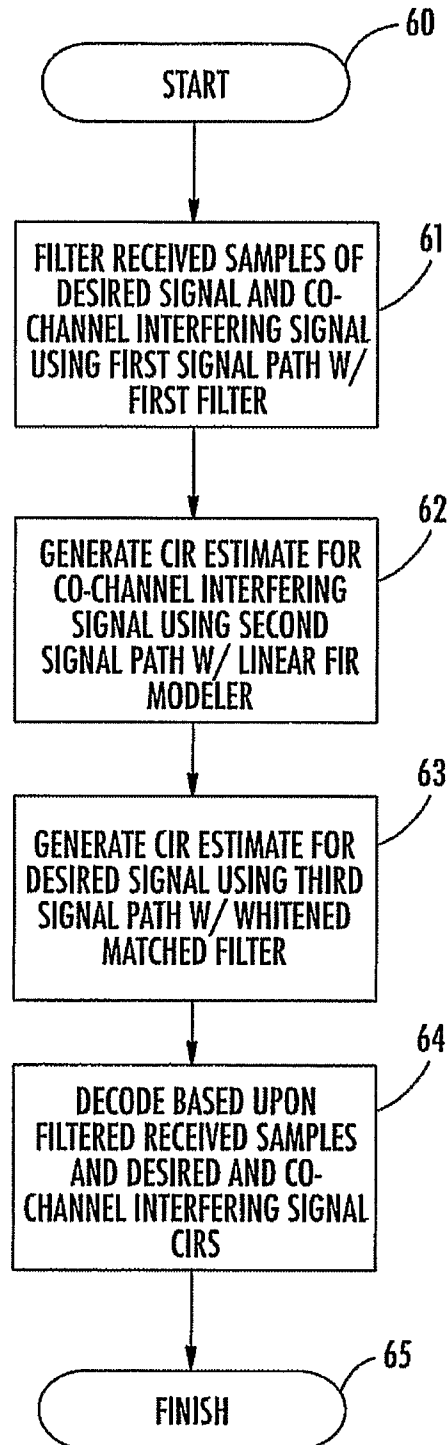


FIG. 1





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**FIG. 4**

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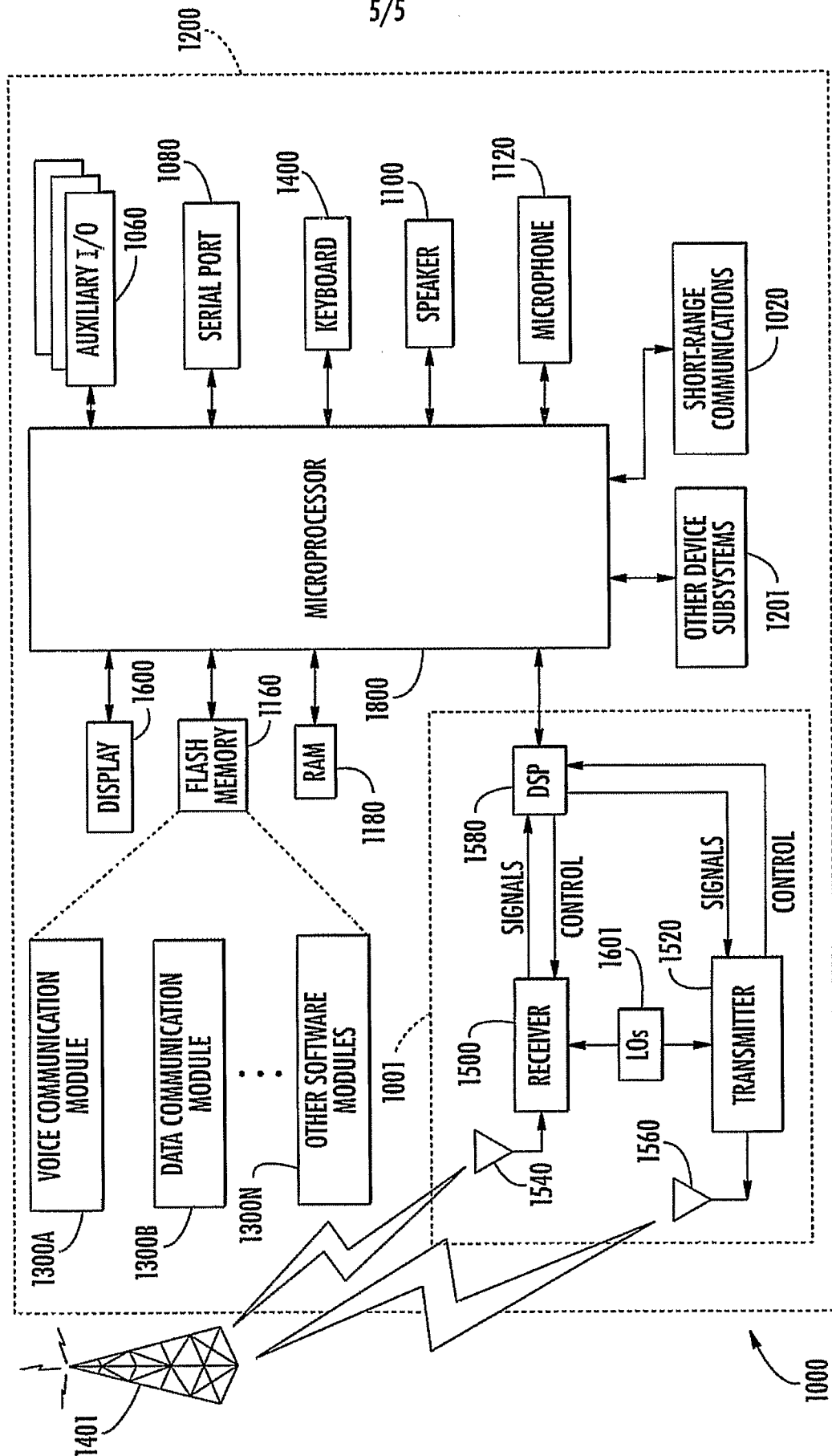


FIG. 5

INTERNATIONAL SEARCH REPORT

International application No.
PCT/CA2006/001378

A. CLASSIFICATION OF SUBJECT MATTER

IPC: **H04B 1/10** (2006.01) , **H03M 13/41** (2006.01) , **H04B 1/16** (2006.01) , **H04Q 7/32** (2006.01)

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC: **H04B 1/10** (2006.01) , **H03M 13/41** (2006.01) , **H04B 1/16** (2006.01) , **H04Q 7/32** (2006.01)

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic database(s) consulted during the international search (name of database(s) and, where practicable, search terms used)

IEEEXplore, West, Canadian Patents Database

Keywords: Viterbi, filter, FIR, finite, impulse response, matched filter, white*, co-channel, training sequence

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US6330294 (Ansbro et al.) 11 December 2001 (11-12-2001) * column 5, lines 36-55 * * column 9, line 53 - column 10, line 27 *	1-20
A	US2004-0017863 (Learned) 29 January 2004 (29-01-2004) * paragraphs 0004, 0006, 0007 *	1-20
A	US2004-0081074 (Piechocki) 29 April 2004 (29-04-2004) * whole document *	1-20
A	US2004-0234004 (Ketchum et al.) 25 November 2004 (25-11-2004) * whole document *	1-20

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents :	"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"A" document defining the general state of the art which is not considered to be of particular relevance	"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"E" earlier application or patent but published on or after the international filing date	"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"&" document member of the same patent family
"O" document referring to an oral disclosure, use, exhibition or other means	
"P" document published prior to the international filing date but later than the priority date claimed	

Date of the actual completion of the international search

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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/CA2006/001378

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