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(54) **HIGH-RELIABILITY COMPUTER INTERFACE FOR WIRELESS INPUT DEVICES**

(76) Inventors: **Martin George Morris**, Vista, CA (US); **Krishnasamy Anandakumar**, San Diego, CA (US); **Suresh Kumar Singamsetty**, Carlsbad, CA (US); **Dennis Ching Chung Kwan**, San Diego, CA (US); **Hock Thye Law**, Carlsbad, CA (US)

Correspondence Address:
George O Saile and Assocs
28 Davis Ave
Poughkeepsie, NY 12603 (US)

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Related U.S. Application Data

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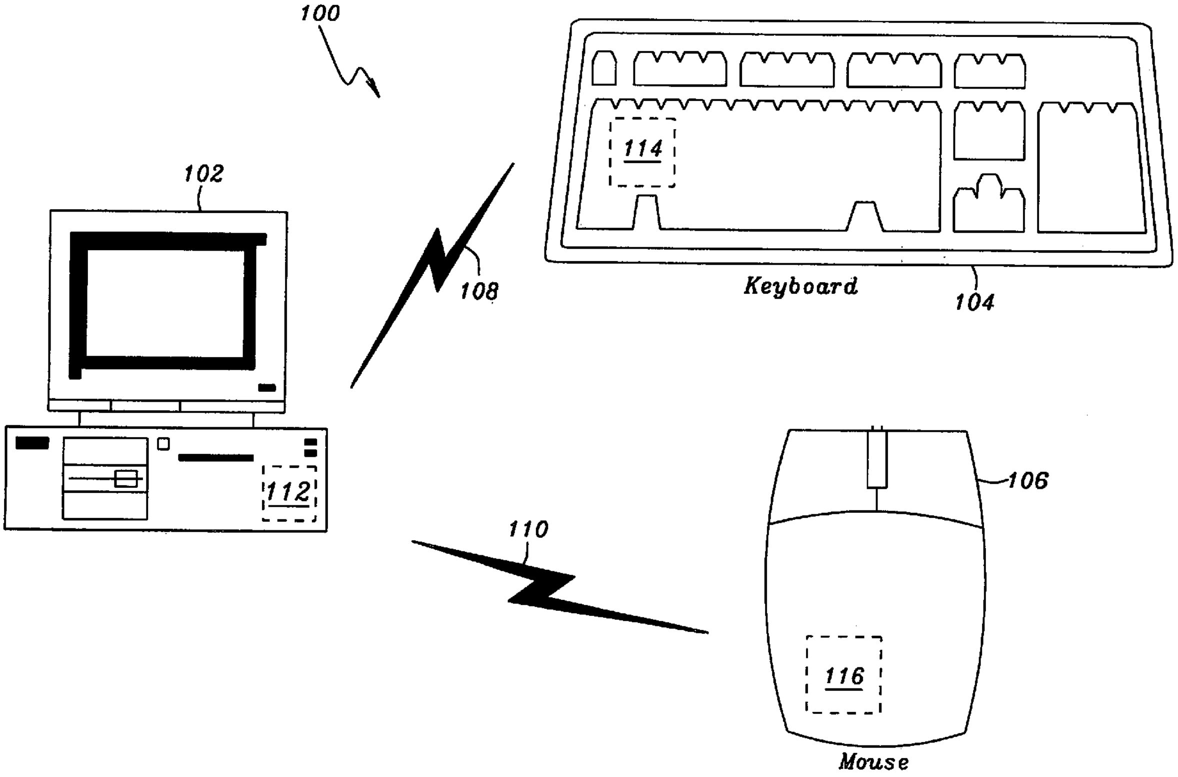
Publication Classification

(51) **Int. Cl.**^{7} **G09G 5/08**

(52) **U.S. Cl.** **345/158**

(57) **ABSTRACT**

A computing system wherein communication between a host computer and peripheral units, e.g. computer mouse and keyboard, is performed using RF signals. The host computer and the peripheral units each contain a transceiver for managing and transmitting the RF communication messages. An acknowledgement is sent by the receiving transceiver to the sending transceiver to signify that the message was successfully received. If no acknowledgement is received by the sending transceiver, a subsequent RF communication message is sent until an acknowledgement is received. A sleep mode is invoked between messages to conserve battery power in the peripheral units, and the peripheral units send a report message to the host when awaking periodically, or by a user demand, from the sleep mode signifying that the peripheral unit is active and ready to send or receive messages.



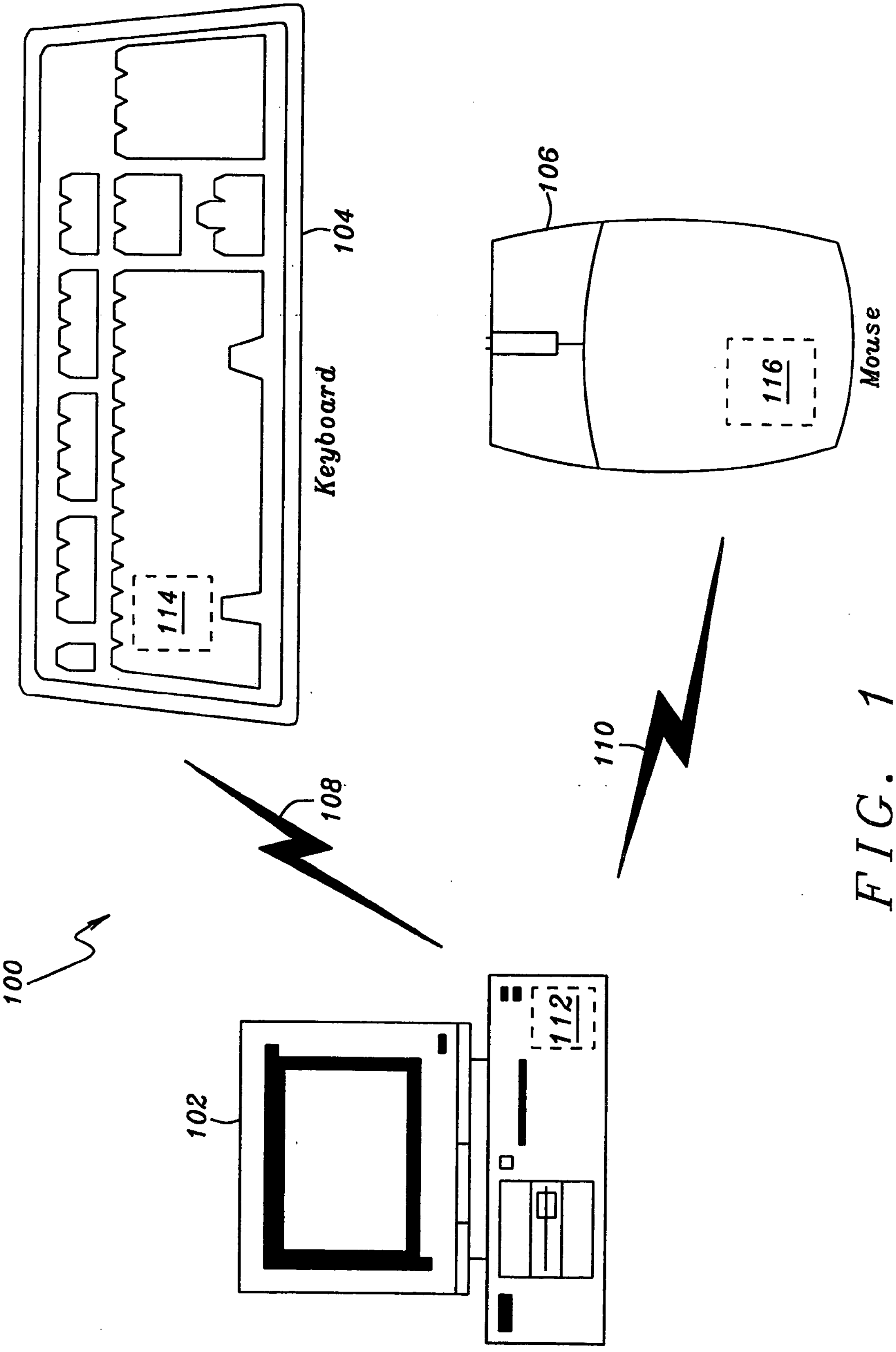


FIG. 1

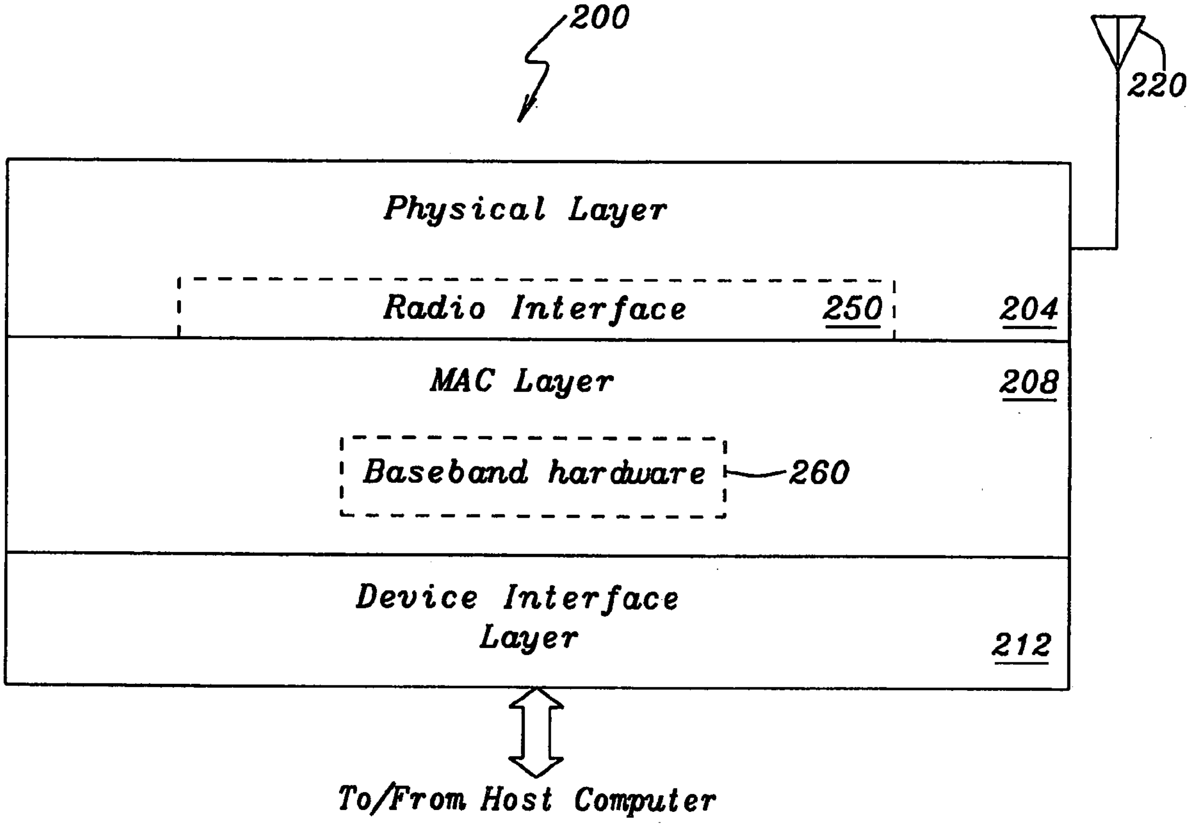

200
220
Physical Layer
Radio Interface
250
204
MAC Layer
208
Baseband hardware
260
Device Interface Layer
212
To/From Host Computer

FIG. 2

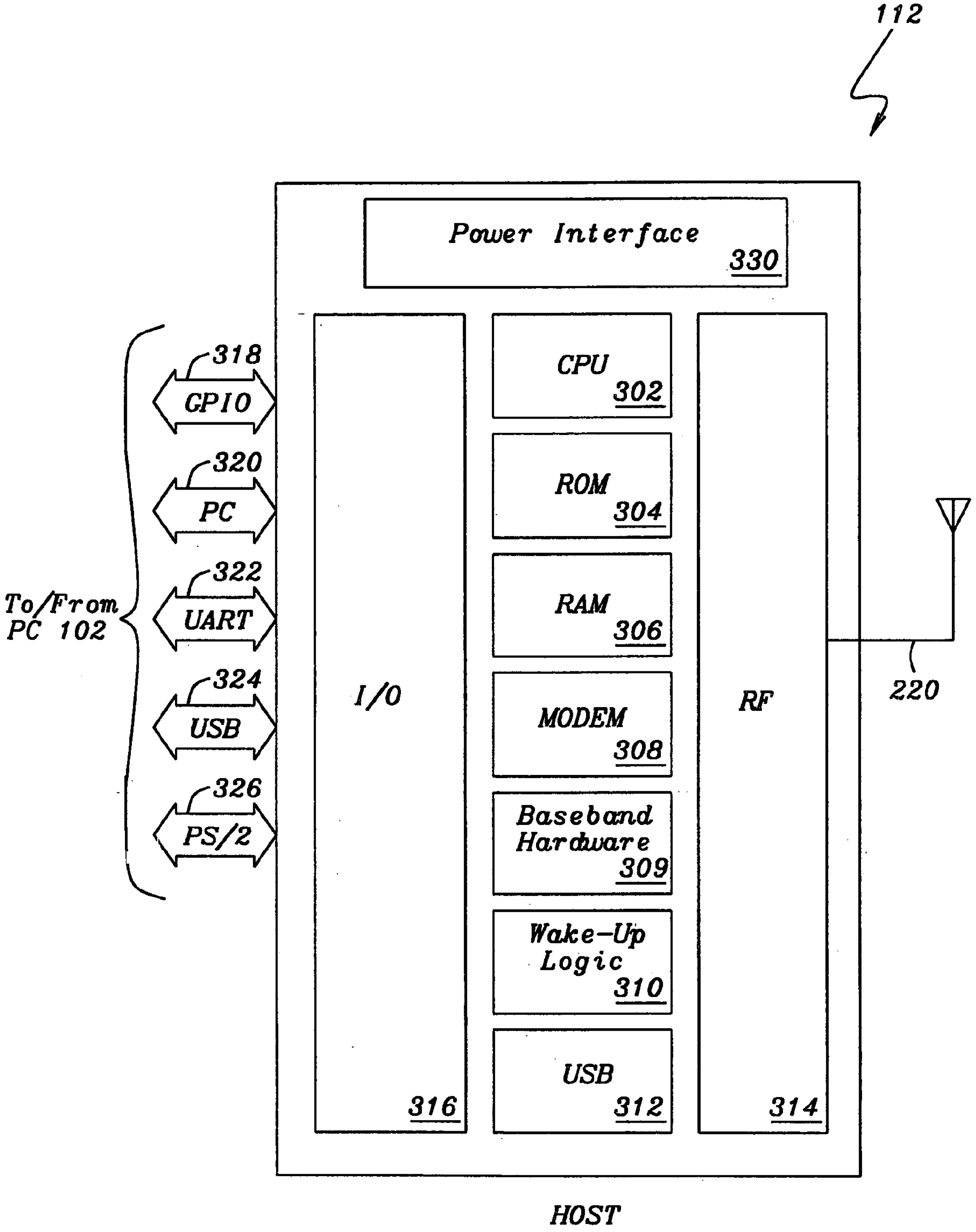

112
Power Interface
330
CPU
302
ROM
304
RAM
306
MODEM
308
Baseband Hardware
309
Wake-Up Logic
310
USB
312
I/O
316
RF
314
220
318
GPIO
320
PC
322
UART
324
USB
326
PS/2
To/From PC 102
HOST

FIG. 3

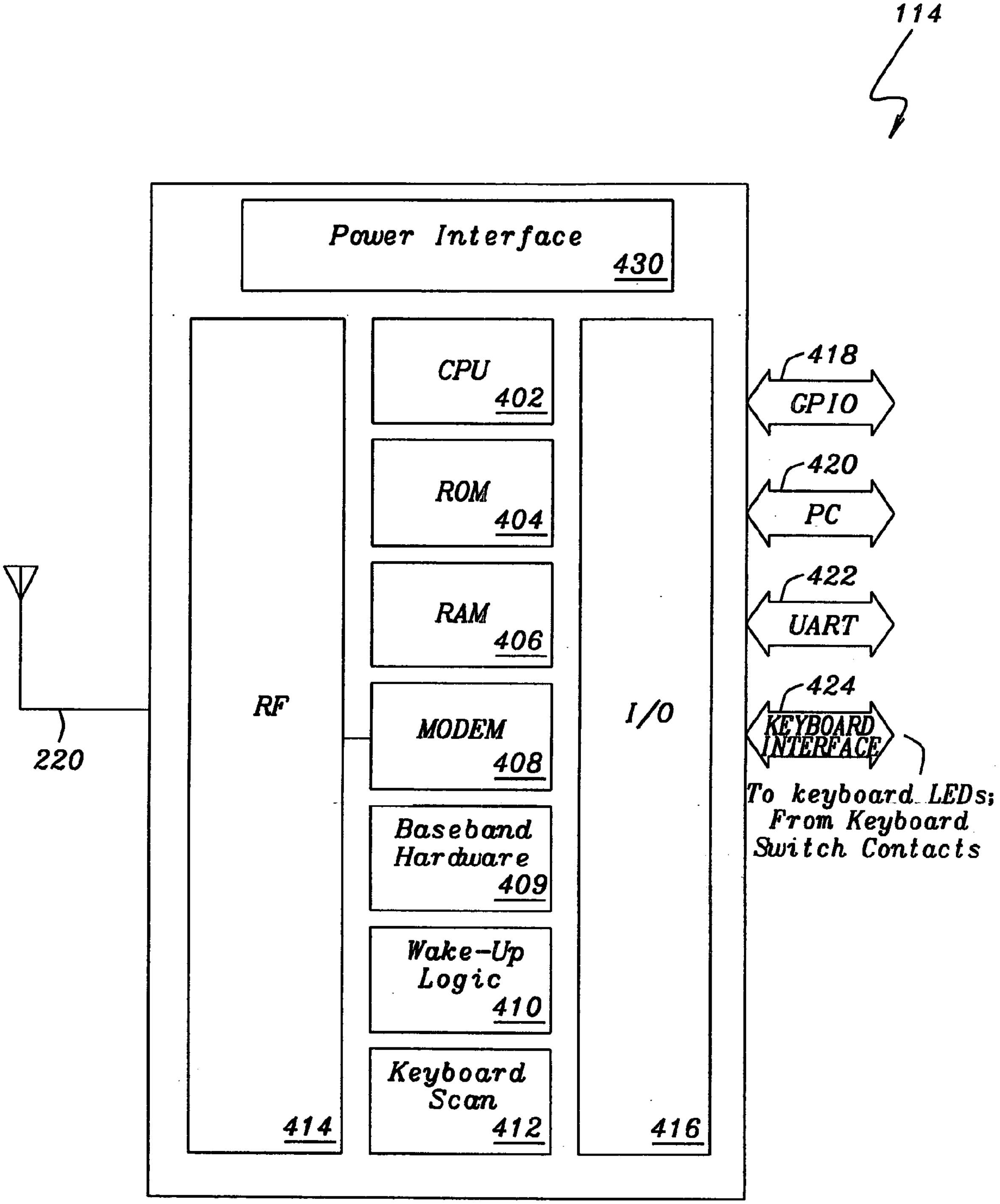

114
Power Interface
430
CPU
402
ROM
404
RAM
406
MODEM
408
Baseband Hardware
409
Wake-Up Logic
410
Keyboard Scan
412
RF
414
I/O
416
418
GPIO
420
PC
422
UART
424
KEYBOARD INTERFACE
To keyboard LEDs;
From Keyboard Switch Contacts
220

FIG. 4

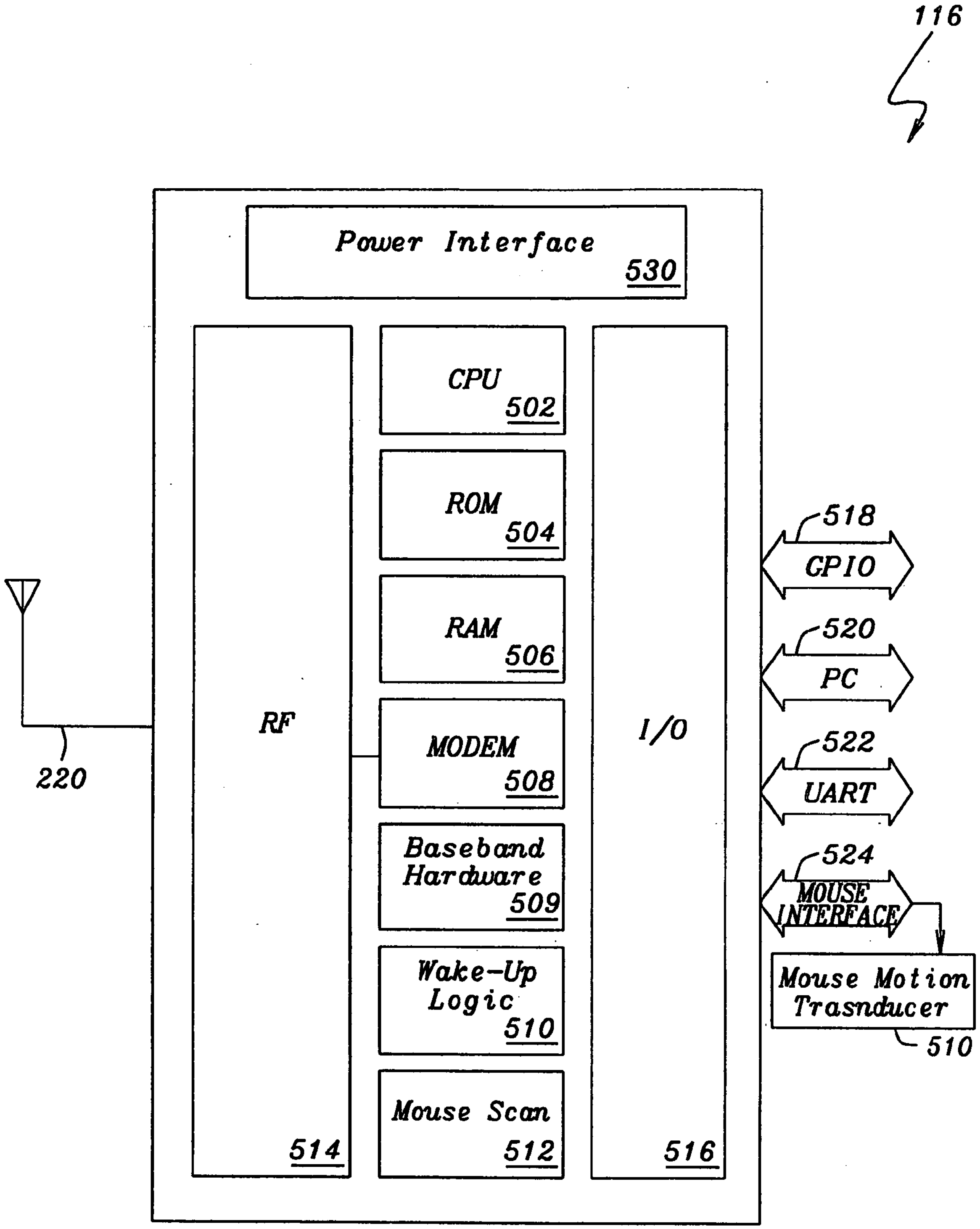

116
Power Interface
530
CPU
502
ROM
504
RAM
506
MODEM
508
Baseband Hardware
509
Wake-Up Logic
510
Mouse Scan
512
RF
514
I/O
516
518
GPIO
520
PC
522
UART
524
MOUSE INTERFACE
Mouse Motion Trasnducer
510
220

FIG. 5

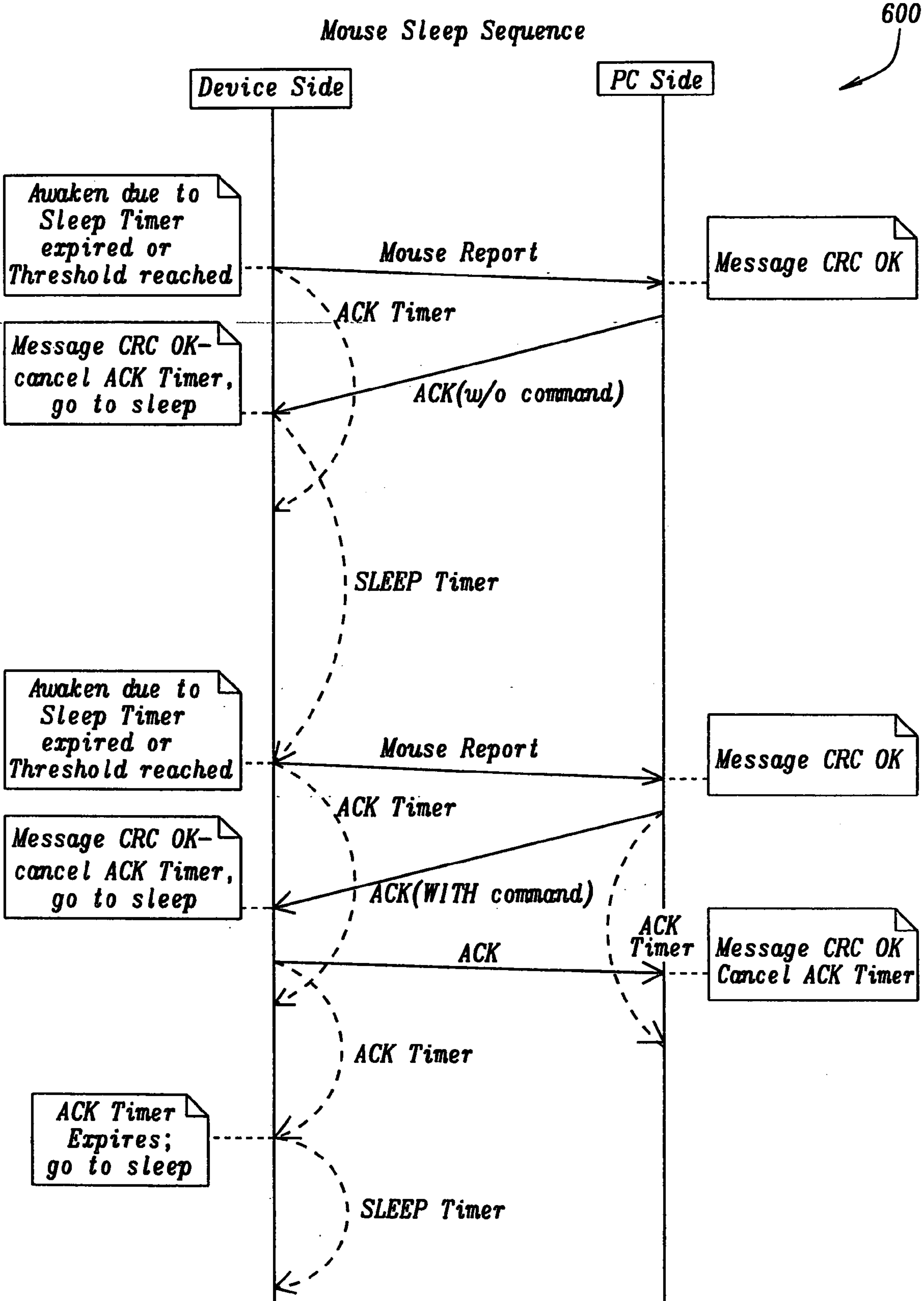

Mouse Sleep Sequence
600
Device Side
PC Side
Awaken due to Sleep Timer expired or Threshold reached
Mouse Report
Message CRC OK
ACK Timer
Message CRC OK-cancel ACK Timer, go to sleep
ACK(w/o command)
SLEEP Timer
Awaken due to Sleep Timer expired or Threshold reached
Mouse Report
Message CRC OK
ACK Timer
Message CRC OK-cancel ACK Timer, go to sleep
ACK(WITH command)
ACK Timer
ACK
Message CRC OK Cancel ACK Timer
ACK Timer
ACK Timer Expires; go to sleep
SLEEP Timer

FIG. 6

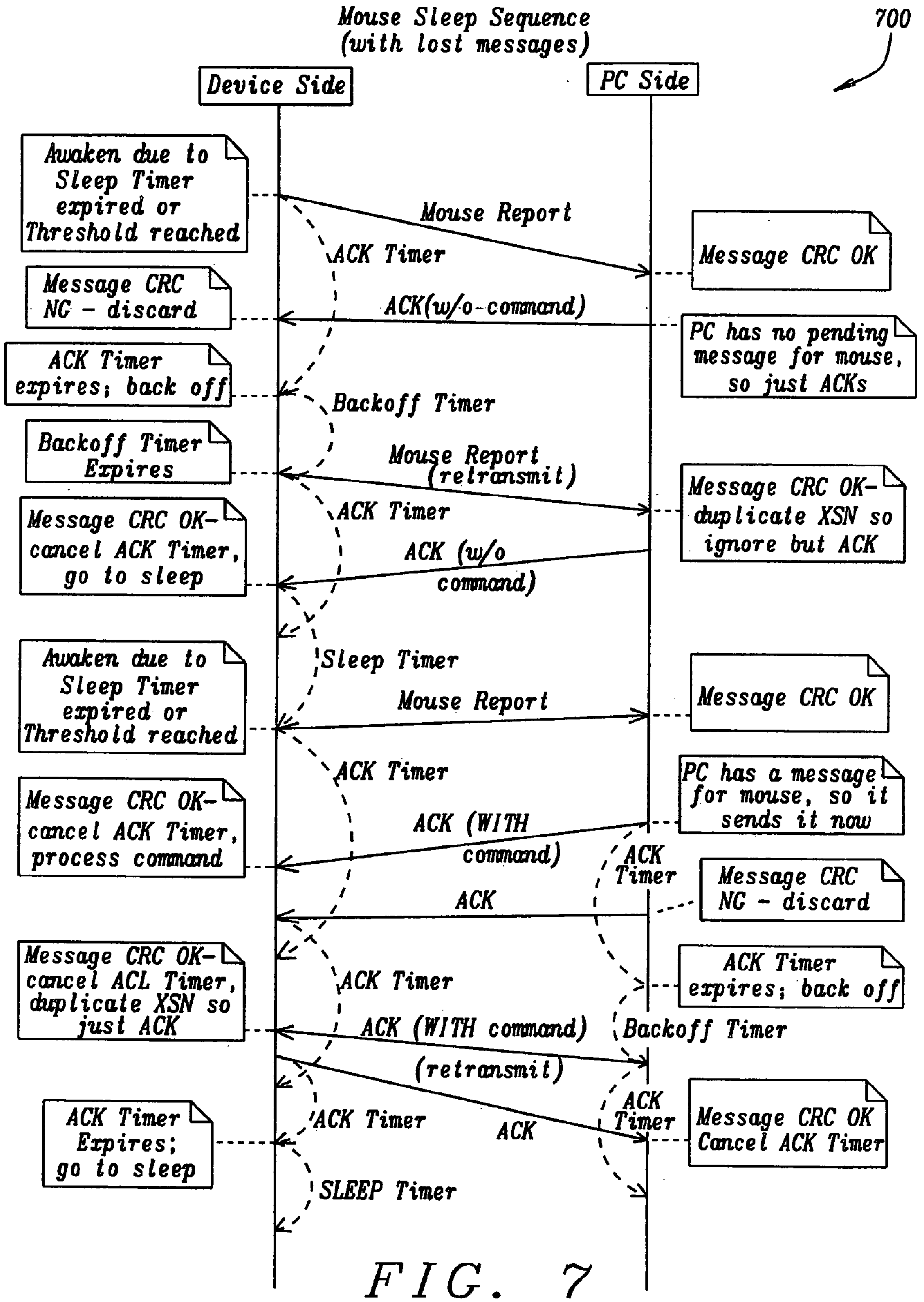

Mouse Sleep Sequence
(with lost messages)
700
Device Side
PC Side
Awaken due to Sleep Timer expired or Threshold reached
Mouse Report
ACK Timer
Message CRC OK
Message CRC NG - discard
ACK(w/o-command)
PC has no pending message for mouse, so just ACKs
ACK Timer expires; back off
Backoff Timer
Backoff Timer Expires
Mouse Report (retransmit)
Message CRC OK- duplicate XSN so ignore but ACK
ACK Timer
Message CRC OK- cancel ACK Timer, go to sleep
ACK (w/o command)
Sleep Timer
Awaken due to Sleep Timer expired or Threshold reached
Mouse Report
Message CRC OK
ACK Timer
PC has a message for mouse, so it sends it now
Message CRC OK- cancel ACK Timer, process command
ACK (WITH command)
ACK Timer
Message CRC NG - discard
ACK
ACK Timer expires; back off
Message CRC OK- cancel ACL Timer, duplicate XSN so just ACK
ACK Timer
ACK (WITH command)
Backoff Timer
(retransmit)
ACK Timer Expires; go to sleep
ACK Timer
ACK
ACK Timer
Message CRC OK Cancel ACK Timer
SLEEP Timer

FIG. 7

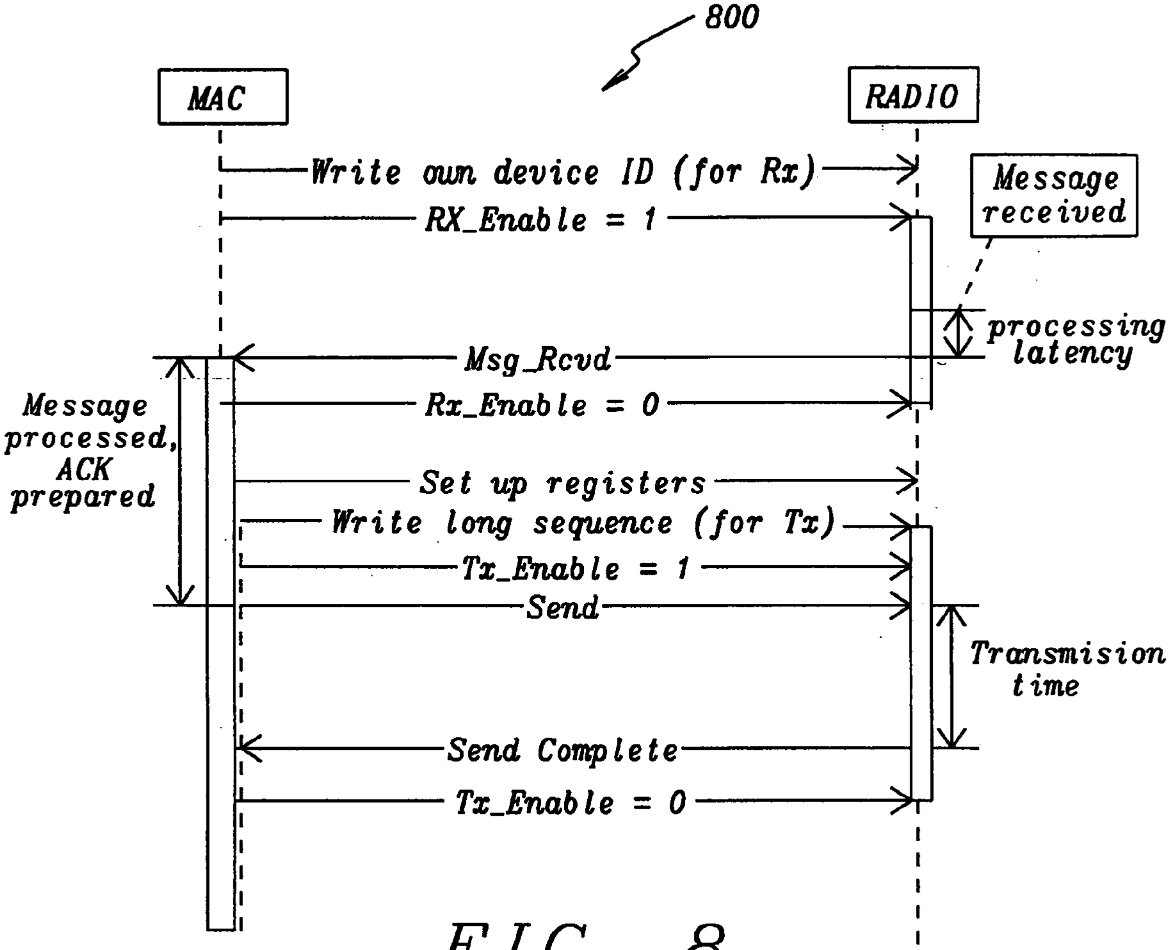

800
MAC
RADIO
Write own device ID (for Rx)
Message received
RX_Enable = 1
processing latency
Msg_Rcvd
Message processed, ACK prepared
Rx_Enable = 0
Set up registers
Write long sequence (for Tx)
Tx_Enable = 1
Send
Transmision time
Send Complete
Tx_Enable = 0

FIG. 8

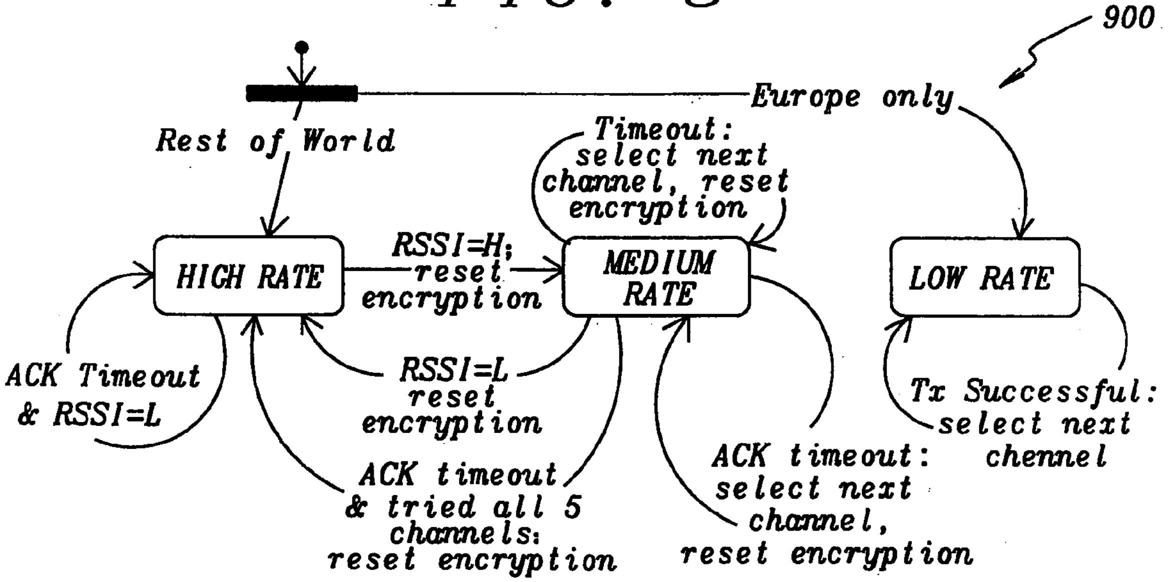

900
Europe only
Rest of World
Timeout: select next channel, reset encryption
HIGH RATE
RSSI=H; reset encryption
MEDIUM RATE
LOW RATE
ACK Timeout & RSSI=L
RSSI=L reset encryption
ACK timeout & tried all 5 channels: reset encryption
ACK timeout: select next channel, reset encryption
Tx Successful: select next chennel

FIG. 9

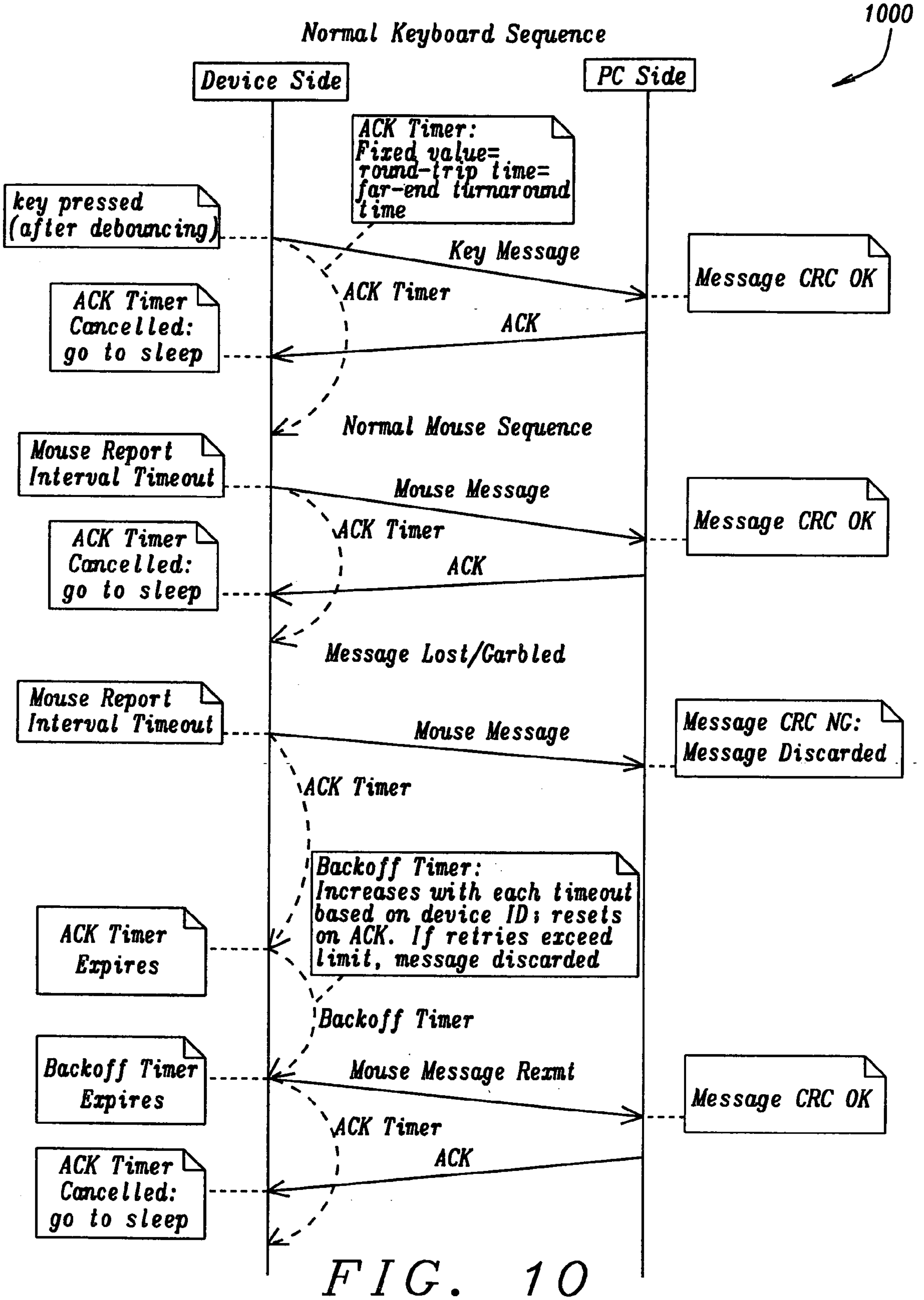

1000
Normal Keyboard Sequence
Device Side
PC Side
ACK Timer:
Fixed value=
round-trip time=
far-end turnaround
time
key pressed
(after debouncing)
Key Message
Message CRC OK
ACK Timer
ACK Timer
Cancelled:
go to sleep
ACK
Normal Mouse Sequence
Mouse Report
Interval Timeout
Mouse Message
Message CRC OK
ACK Timer
ACK Timer
Cancelled:
go to sleep
ACK
Message Lost/Garbled
Mouse Report
Interval Timeout
Mouse Message
Message CRC NG:
Message Discarded
ACK Timer
Backoff Timer:
Increases with each timeout
based on device ID; resets
on ACK. If retries exceed
limit, message discarded
ACK Timer
Expires
Backoff Timer
Backoff Timer
Expires
Mouse Message Rexmt
Message CRC OK
ACK Timer
ACK
ACK Timer
Cancelled:
go to sleep

FIG. 10

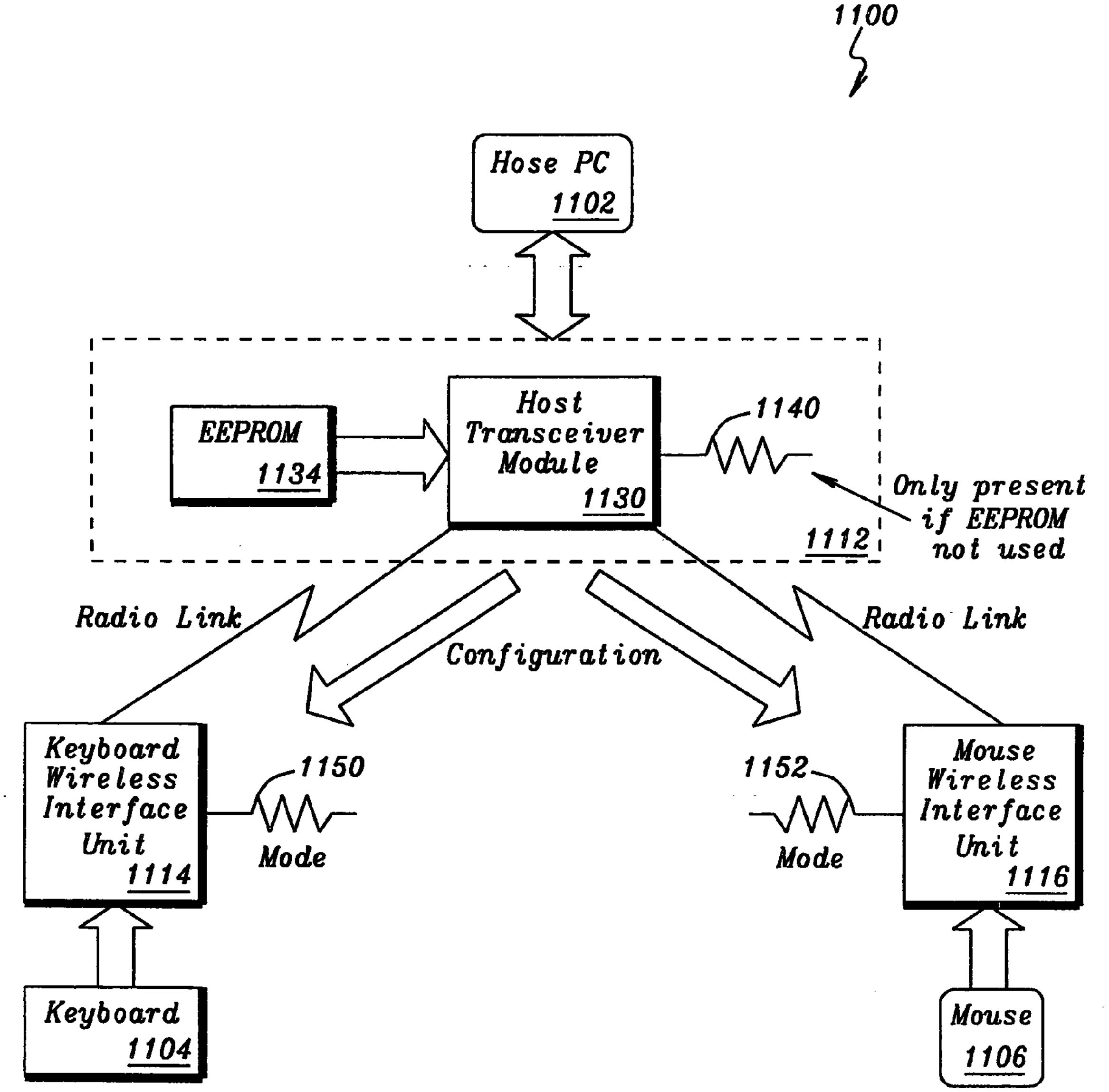

1100
Hose PC
1102
EEPROM
1134
Host Transceiver Module
1130
1140
Only present if EEPROM not used
1112
Radio Link
Configuration
Radio Link
Keyboard Wireless Interface Unit
1114
1150
Mode
1152
Mode
Mouse Wireless Interface Unit
1116
Keyboard
1104
Mouse
1106

FIG. 11

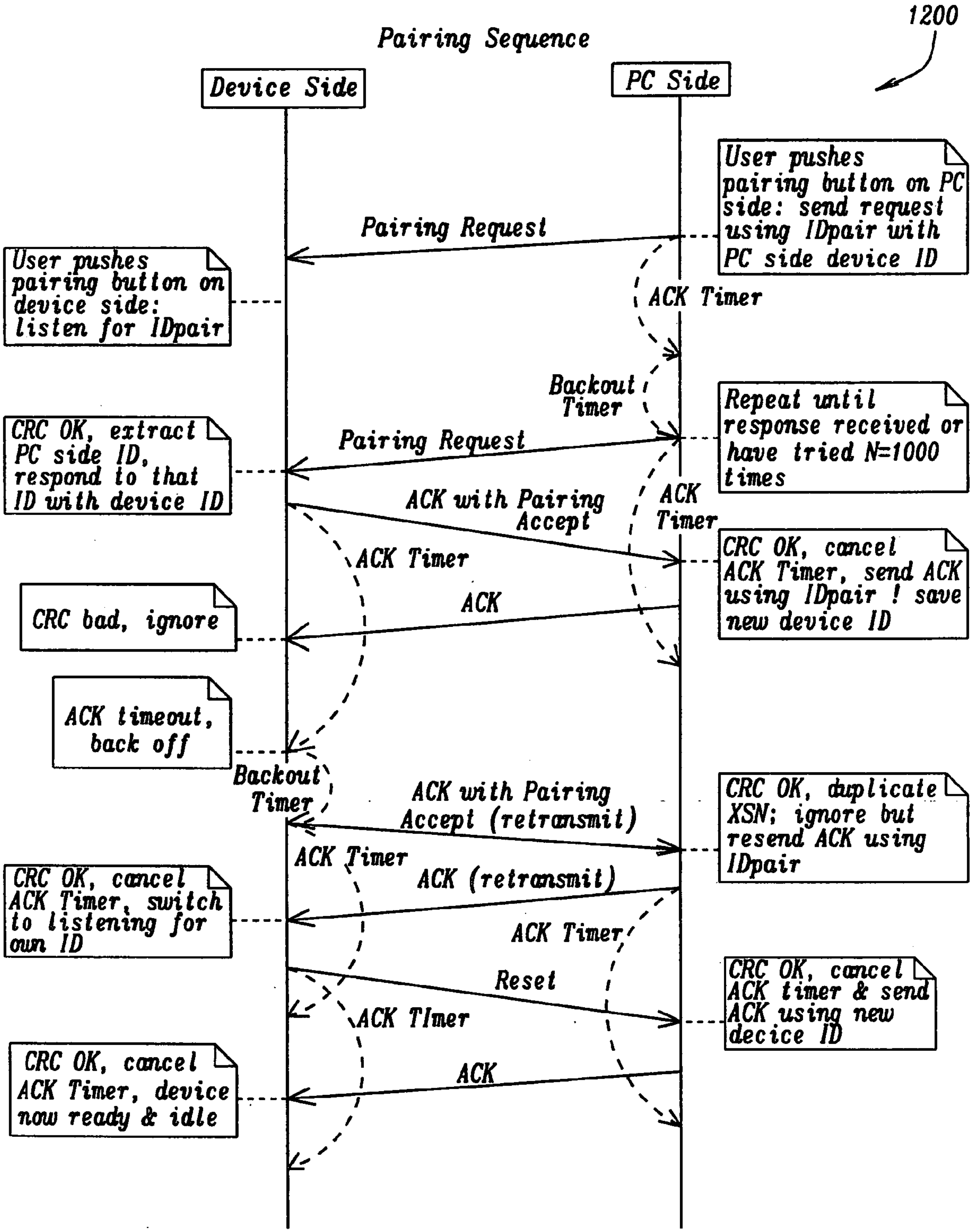

1200
Pairing Sequence
Device Side
PC Side
User pushes pairing button on PC side: send request using IDpair with PC side device ID
Pairing Request
User pushes pairing button on device side: listen for IDpair
ACK Timer
Backout Timer
Repeat until response received or have tried N=1000 times
Pairing Request
CRC OK, extract PC side ID, respond to that ID with device ID
ACK with Pairing Accept
ACK Timer
ACK Timer
CRC OK, cancel ACK Timer, send ACK using IDpair ! save new device ID
ACK
CRC bad, ignore
ACK timeout, back off
Backout Timer
ACK with Pairing Accept (retransmit)
CRC OK, duplicate XSN; ignore but resend ACK using IDpair
ACK Timer
ACK (retransmit)
CRC OK, cancel ACK Timer, switch to listening for own ID
ACK Timer
Reset
CRC OK, cancel ACK timer & send ACK using new decice ID
ACK TImer
ACK
CRC OK, cancel ACK Timer, device now ready & idle

FIG. 12

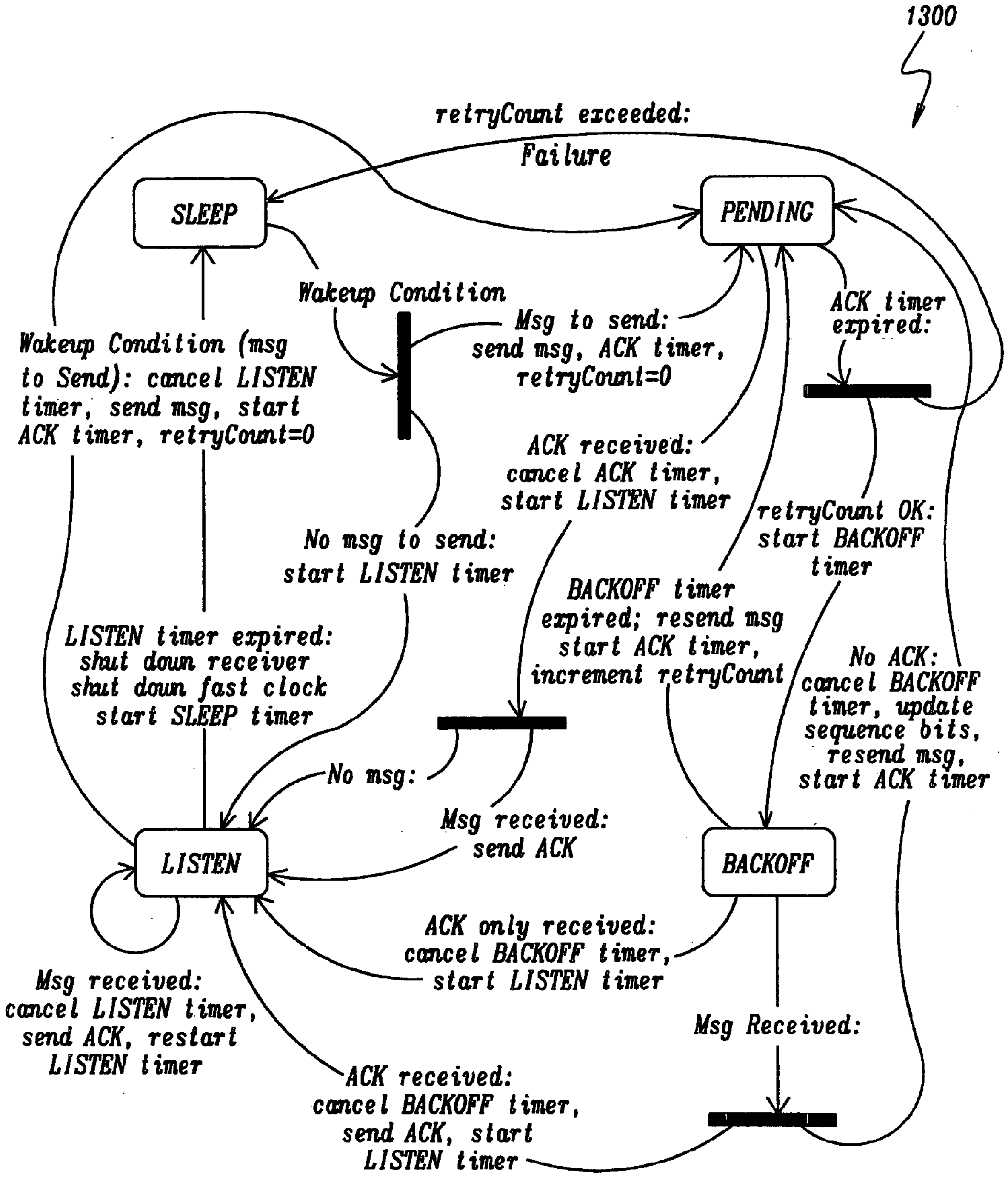

1300
retryCount exceeded:
Failure
SLEEP
PENDING
Wakeup Condition
Msg to send:
send msg, ACK timer,
retryCount=0
ACK timer
expired:
Wakeup Condition (msg
to Send): cancel LISTEN
timer, send msg, start
ACK timer, retryCount=0
ACK received:
cancel ACK timer,
start LISTEN timer
retryCount OK:
start BACKOFF
timer
No msg to send:
start LISTEN timer
BACKOFF timer
expired; resend msg
start ACK timer,
increment retryCount
LISTEN timer expired:
shut down receiver
shut down fast clock
start SLEEP timer
No ACK:
cancel BACKOFF
timer, update
sequence bits,
resend msg,
start ACK timer
No msg:
Msg received:
send ACK
LISTEN
BACKOFF
ACK only received:
cancel BACKOFF timer,
start LISTEN timer
Msg received:
cancel LISTEN timer,
send ACK, restart
LISTEN timer
Msg Received:
ACK received:
cancel BACKOFF timer,
send ACK, start
LISTEN timer

FIG. 13

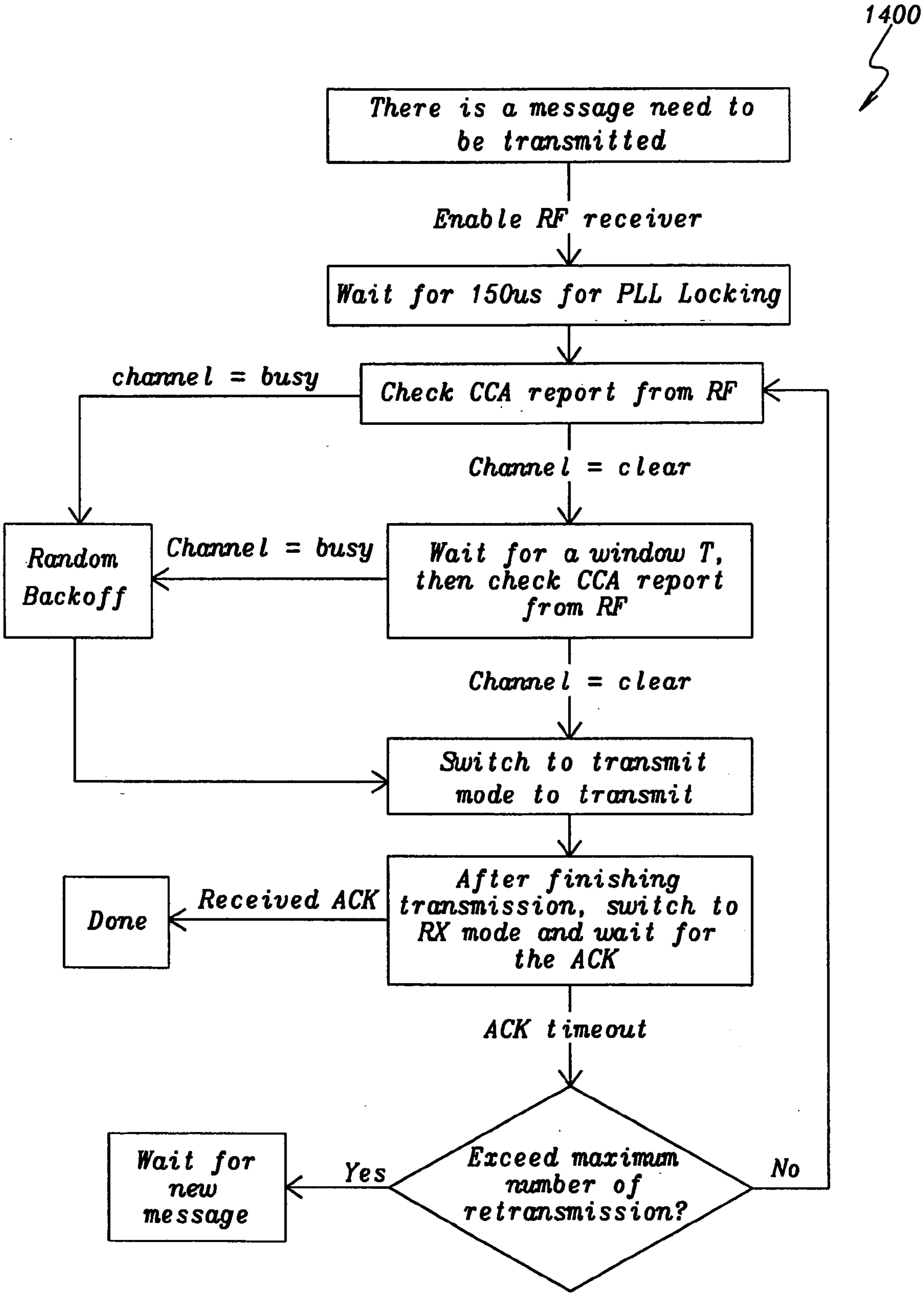

1400
There is a message need to be transmitted
Enable RF receiver
Wait for 150us for PLL Locking
Check CCA report from RF
channel = busy
Channel = clear
Random Backoff
Channel = busy
Wait for a window T, then check CCA report from RF
Channel = clear
Switch to transmit mode to transmit
After finishing transmission, switch to RX mode and wait for the ACK
Received ACK
Done
ACK timeout
Exceed maximum number of retransmission?
Yes
No
Wait for new message

FIG. 14

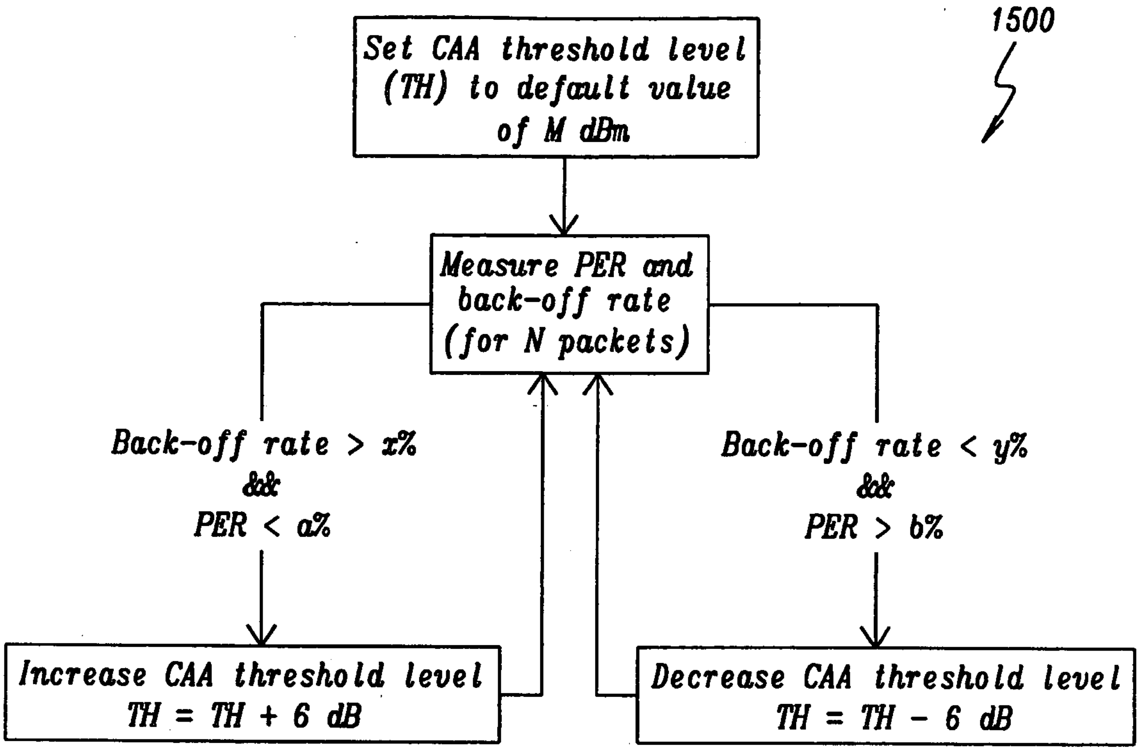

1500
Set CAA threshold level (TH) to default value of M dBm
Measure PER and back-off rate (for N packets)
Back-off rate > x% && PER < a%
Back-off rate < y% && PER > b%
Increase CAA threshold level TH = TH + 6 dB
Decrease CAA threshold level TH = TH - 6 dB

FIG. 15

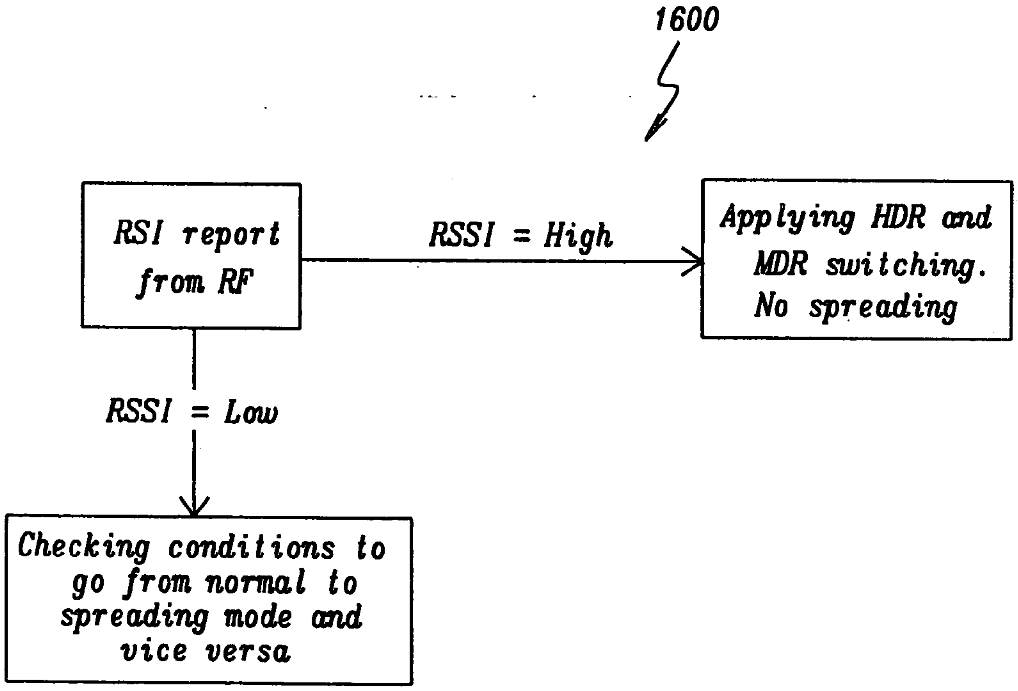

1600
RSI report from RF
RSSI = High
Applying HDR and MDR switching. No spreading
RSSI = Low
Checking conditions to go from normal to spreading mode and vice versa

FIG. 16

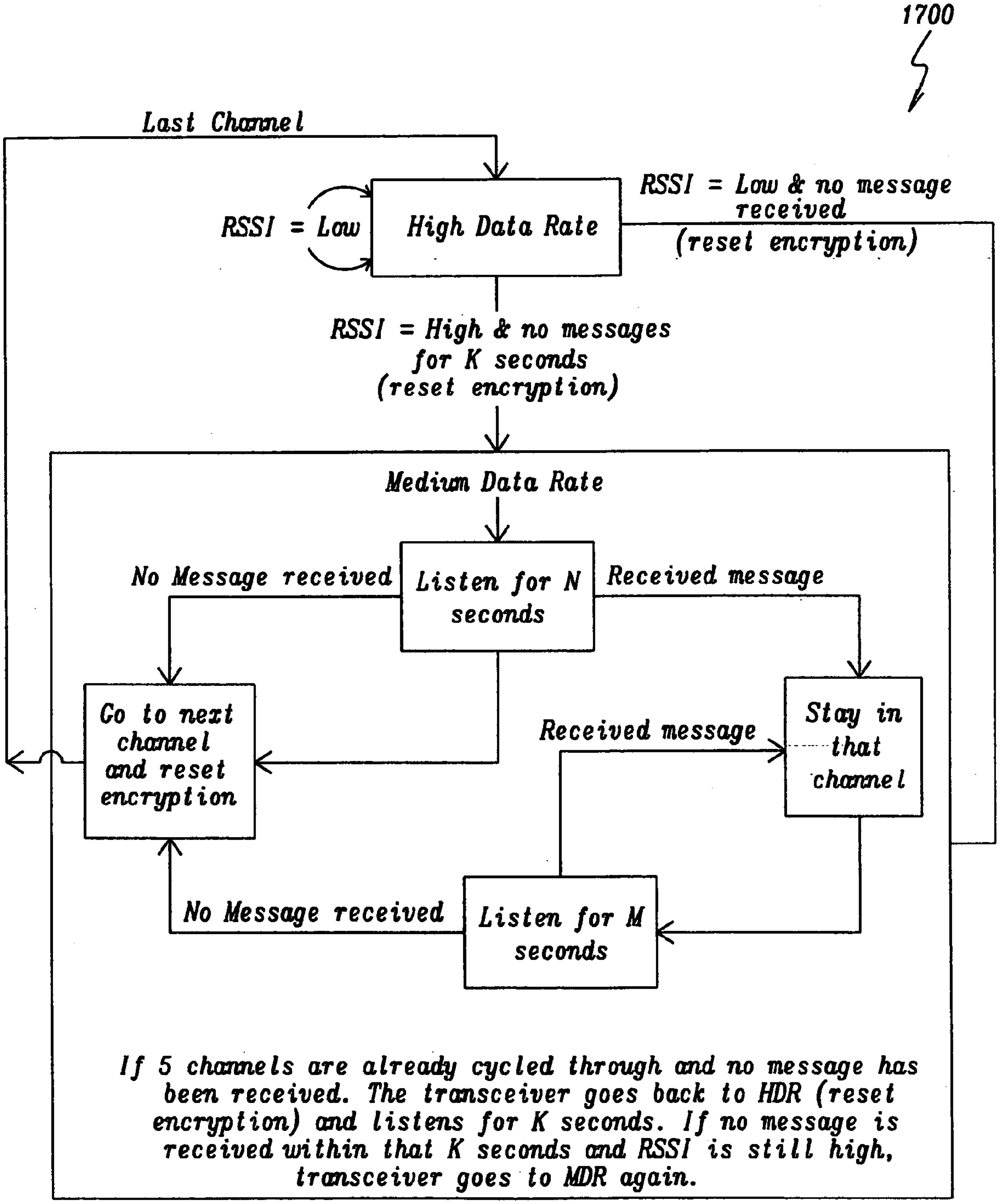

1700
Last Channel
RSSI = Low
High Data Rate
RSSI = Low & no message received
(reset encryption)
RSSI = High & no messages for K seconds
(reset encryption)
Medium Data Rate
No Message received
Listen for N seconds
Received message
Go to next channel and reset encryption
Received message
Stay in that channel
No Message received
Listen for M seconds
If 5 channels are already cycled through and no message has been received. The transceiver goes back to HDR (reset encryption) and listens for K seconds. If no message is received within that K seconds and RSSI is still high, transceiver goes to MDR again.

FIG. 17

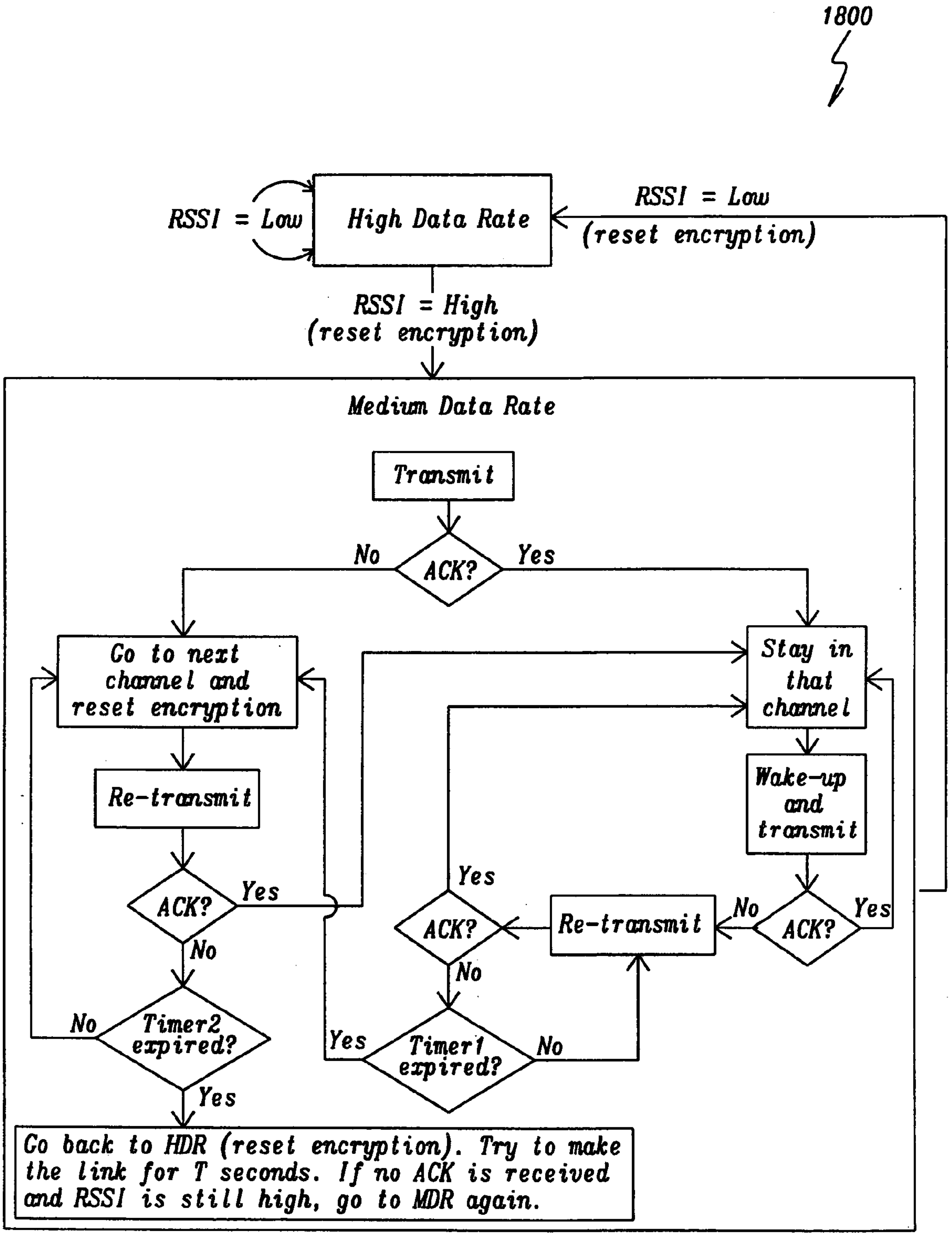

1800
RSSI = Low
High Data Rate
RSSI = Low
(reset encryption)
RSSI = High
(reset encryption)
Medium Data Rate
Transmit
No
ACK?
Yes
Go to next channel and reset encryption
Stay in that channel
Re-transmit
Wake-up and transmit
Yes
ACK?
No
Yes
ACK?
No
Re-transmit
No
ACK?
Yes
No
Timer2 expired?
Yes
Yes
Timer1 expired?
No
Go back to HDR (reset encryption). Try to make the link for T seconds. If no ACK is received and RSSI is still high, go to MDR again.

FIG. 18

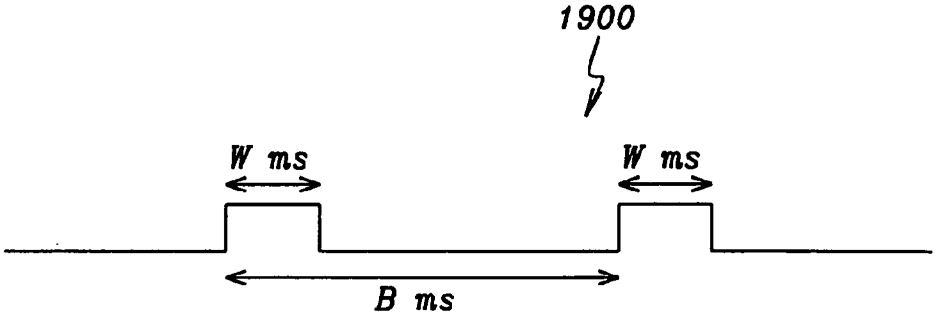

1900
W ms
W ms
B ms

FIG. 19

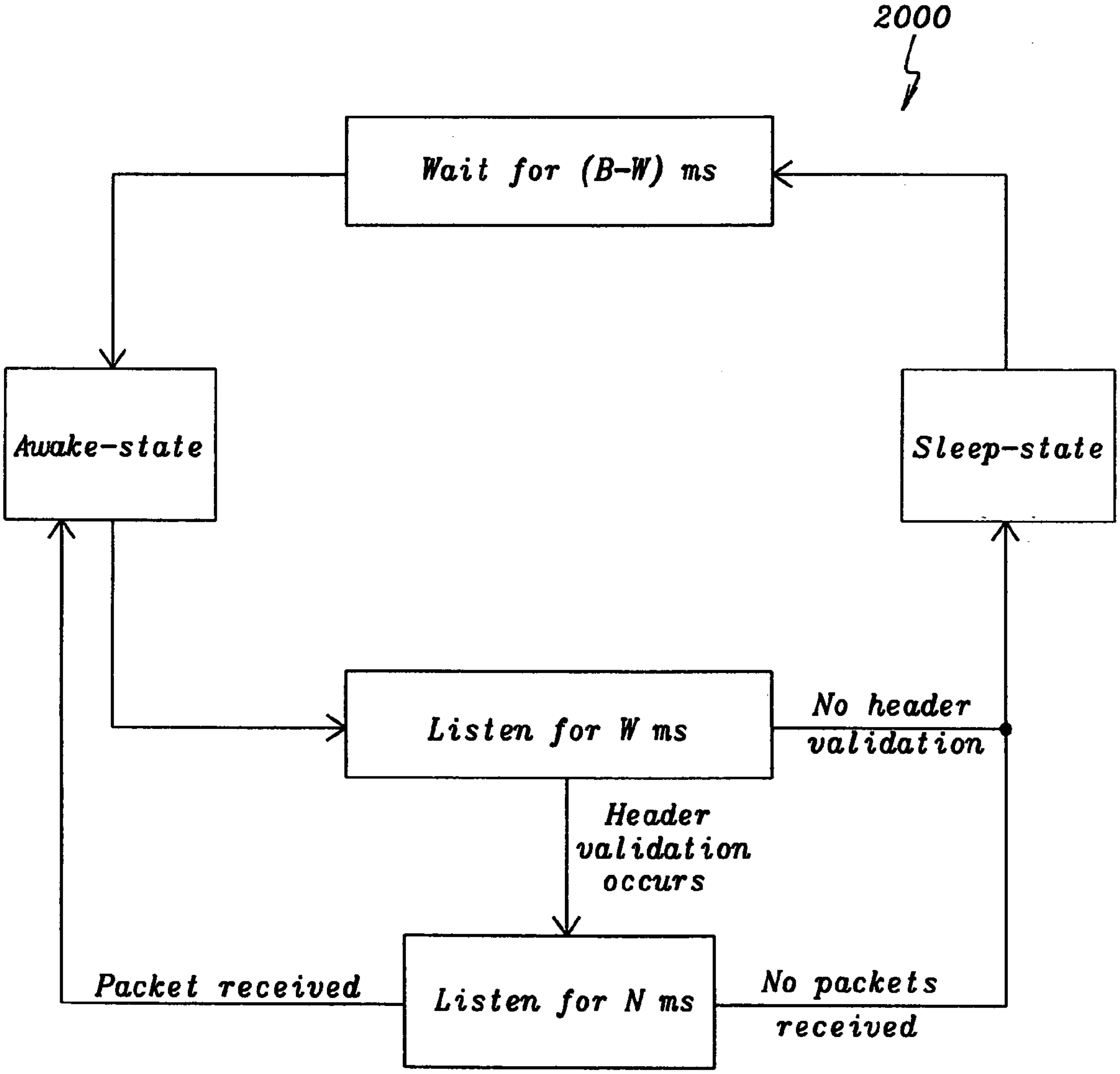

2000
Wait for (B-W) ms
Awake-state
Sleep-state
Listen for W ms
No header validation
Header validation occurs
Listen for N ms
Packet received
No packets received

FIG. 20

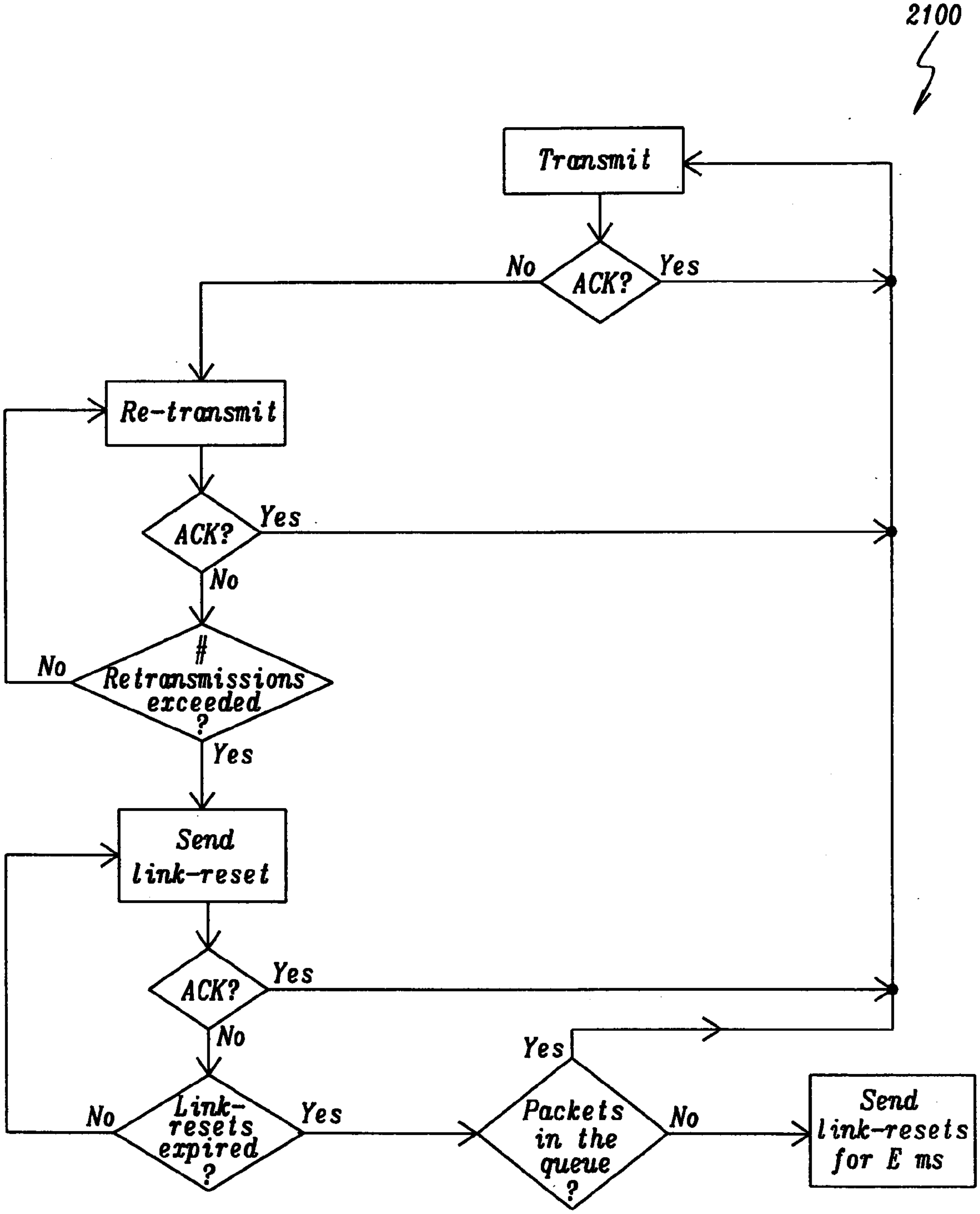

2100
Transmit
ACK?
No
Yes
Re-transmit
ACK?
Yes
No
#
Retransmissions
exceeded
?
No
Yes
Send
link-reset
ACK?
Yes
No
Yes
Link-
resets
expired
?
No
Yes
Packets
in the
queue
?
No
Send
link-resets
for E ms

FIG. 21

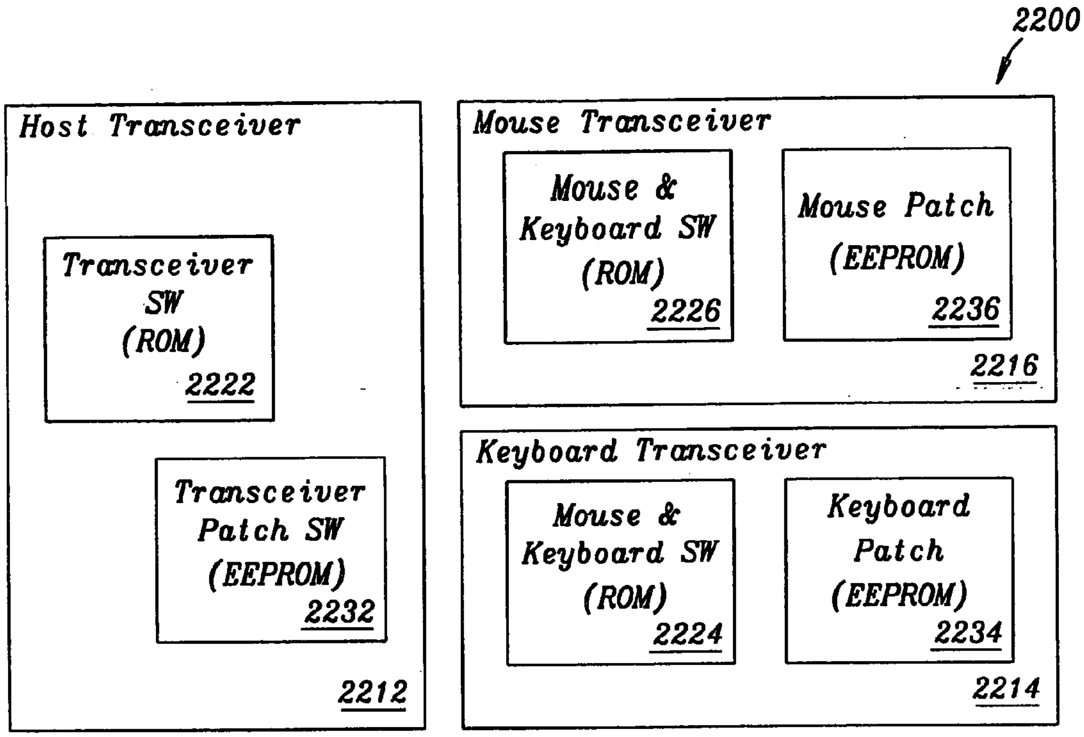

2200
Host Transceiver
Transceiver SW (ROM) 2222
Transceiver Patch SW (EEPROM) 2232
2212
Mouse Transceiver
Mouse & Keyboard SW (ROM) 2226
Mouse Patch (EEPROM) 2236
2216
Keyboard Transceiver
Mouse & Keyboard SW (ROM) 2224
Keyboard Patch (EEPROM) 2234
2214

FIG. 22

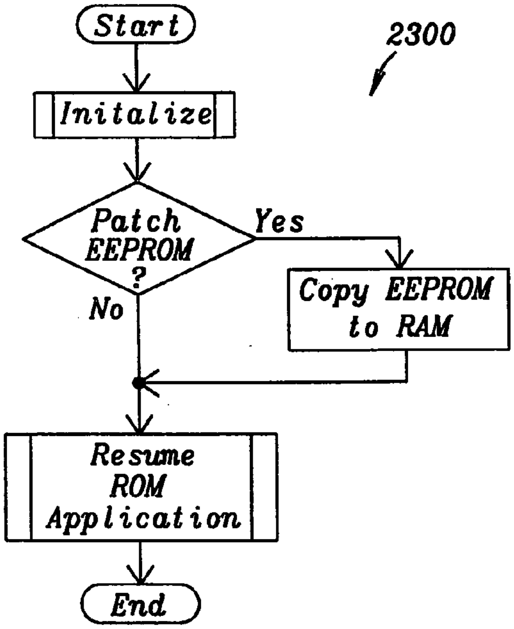


FIG. 23

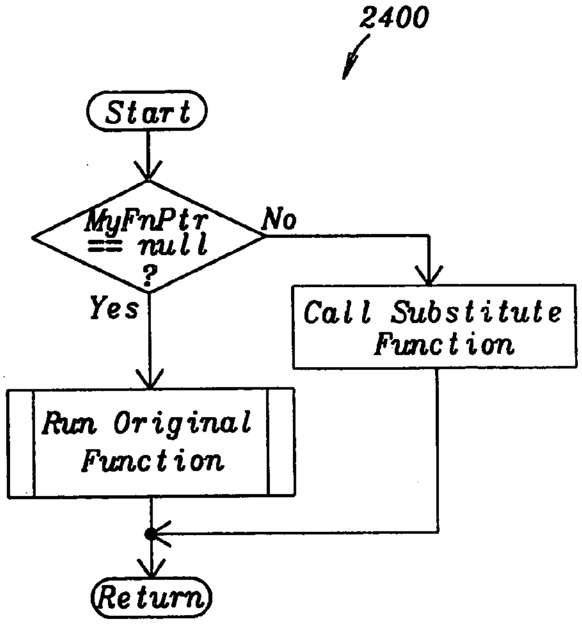


FIG. 24

HIGH-RELIABILITY COMPUTER INTERFACE FOR WIRELESS INPUT DEVICES

[**0001**] This application claims priority to U.S. Provisional Patent Application JAAL-001, "High-Reliability Computer Interface for Wireless Input Device", Ser. No. 60/553,820, filed on Mar. 16, 2004, which is herein incorporated by reference in its entirety.

[**0002**] This application claims priority to U.S. Provisional Patent Application JAAL-002, "Wireless Transceiver System for Computer Input Devices", Ser. No. 60/553,821, filed on Mar. 16, 2004, which is herein incorporated by reference in its entirety.

[**0003**] This application claims priority to U.S. Provisional Patent Application JAAL-003, "Wireless Transceiver System for Computer Input Devices", Ser. No. 60/554,058, filed on Mar. 16, 2004, which is herein incorporated by reference in its entirety.

RELATED PATENT APPLICATION

[**0004**] This application is related to U.S. Patent Application docket number JA05-002, serial number ______, filed on ______, assigned to a common assignee.

FIELD OF THE INVENTION

[**0005**] The present invention relates generally to computer systems and, more particularly, to an interface between a computer and input devices in communication with the computer over wireless links.

BACKGROUND OF THE INVENTION

[**0006**] Various computers and microprocessor-based devices and systems provide one or more user input devices to allow a user to control certain operations. Such an input device may be separated from the host computer or device and thus a communication link and an interface may be implemented to support proper communications between the input device and the host computer or device. Generally, each of the input device and the host computer/device includes appropriate software and hardware, for the communication link and interface.

[**0007**] For example, a typical desktop or laptop computer may have a keyboard and a pointing device for a user to input data or commands for controlling or operating the computer. Examples of the pointing device for computers include a mouse, a touch pad, a trackball, and a pointing stick (IBM laptops). In addition to keyboards and pointing devices, examples of some other user input devices include joysticks and game pads for computers and microprocessor-based game machines, control units for other microprocessor-based devices. In general, a user uses an input button, a control stick, one key or a key combination, or a combination thereof to input data or a command. Circuitry in the input device converts the input data or command into a proper form for transmitting to the computer or device.

[**0008**] Such an input device generally uses a particular communication link to transmit the input data or command to the computer or device. An input device may be a wireless input device using a wireless communication link or a wired link using an electrical cable. Input devices with wired links may be implemented based on the PS/2 keyboard interface, the USB 1.0 and USB 2.0 interfaces, and other interfaces. The wireless communication link may be implemented by a radiation transmitter to send the input to a corresponding radiation receiver at the computer or device. Many wireless input devices use RF radiation links based on different radio interfaces such as IEEE 802.5.14 for low speed links and wireless USB 2.0 and IEEE 1394 for relatively high speed links. Some of these wired or wireless input devices may use the Human Interface Device (HID) protocol over wired or wireless USB links or other non-USB communication links.

[**0009**] Wireless input devices beneficially increase the flexibility of the interaction between a user and a host computer in that no wired connection is required with the host computer. However, given that a wired connection generally provides a source of power for an input device, wireless input devices are required to be self-powered (e.g., battery-powered). Unfortunately, batteries used to power existing wireless input devices typically last for a period of time significantly less than the useful life of such devices. As a consequence, the convenience and value of such devices are diminished as a consequence of the need for regular battery replacement.

[**0010**] Existing wireless input devices are also frequently of limited range and the wireless link established for communication with the host computer is often rather unreliable and/or exhibits a high latency. In addition, such wireless links are often relatively insecure and thus susceptible to eavesdropping or unauthorized monitoring.

BRIEF DESCRIPTION OF THE DRAWINGS

[**0011**] This invention will be described with reference to the accompanying drawings, wherein:

[**0012**] **FIG. 1** is a diagram of a computer system of the present invention incorporating a wireless input interface;

[**0013**] **FIG. 2** is a diagram of the layered architecture of the present invention for the wireless unit contained in the host computer;

[**0014**] **FIG. 3** is a block diagram of the wireless unit of the present invention;

[**0015**] **FIG. 4** is a block diagram of the present invention depicting an exemplary embodiment of the wireless unit;

[**0016**] **FIG. 5** is a block diagram of the present invention depicting an exemplary embodiment of the wireless unit;

[**0017**] **FIG. 6** is an event trace diagram of the present invention for mouse sleep sequence;

[**0018**] **FIG. 7** is an event trace diagram of the present invention for mouse sleep sequence with lost messages;

[**0019**] **FIG. 8** is an event trace diagram of the present invention for enabling of the transmitter/receiver within the RF units;

[**0020**] **FIG. 9** is a state transition diagram of the present invention demonstrating the manner in which the data rate and channel of the wireless unit are changed;

[**0021**] **FIG. 10** is an event trace diagram of the present invention for normal keyboard sequence;

[**0022**] **FIG. 11** is shown a computer system of the present invention;

[0023] FIG. 12 is an event trace diagram of the present invention demonstrating the messages exchanged during a pairing operation;

[0024] FIG. 13 is a state transition diagram of the present invention;

[0025] FIG. 14 is a flowchart of the present invention of a carrier sense/clear channel assessment procedure;

[0026] FIG. 15 is a flowchart of the procedure for dynamically adjusting the CCA threshold level used by the RF unit;

[0027] FIG. 16 is a high-level flow diagram representative of a general approach to interference handling consistent with the present invention;

[0028] FIG. 17 is a flow diagram of the present invention for the method in which a host transceiver converts between HDR and MDR modes;

[0029] FIG. 18 is a flow diagram of the present invention for the method in which a device transceiver converts between operations within the HDR and MDR modes;

[0030] FIG. 19 is a timing diagram of the present invention for the transition of the host transceiver into and out of "awake" and "sleep state" operation;

[0031] FIG. 20 is a state transition diagram of the present invention for operation of the host transceiver when in Suspend mode;

[0032] FIG. 21 is a state transition diagram of the present invention depicting the modifications to the messaging protocol of the mouse transceiver upon entry of the host transceiver into Suspend mode;

[0033] FIG. 22 is a high-level diagram of the present invention showing the incorporation of EEPROM in the wireless transceivers;

[0034] FIG. 23 is a flow diagram of the present invention for the inclusion of a patch EEPROM in the wireless transceivers; and

[0035] FIG. 24 is a flow diagram of the present invention for substituting a new function for a default function.

DETAILED DESCRIPTION OF THE INVENTION SYSTEM OVERVIEW

[0036] Turning now to FIG. 1, a computer system 100 incorporating a wireless input interface in accordance with the invention includes a host computer 102, a wireless keyboard 104 and a wireless pointing device or "mouse"106. As illustrated in FIG. 1, the wireless keyboard 104 and the wireless mouse 106 are in communication with the host computer 102 over wireless communication links 108 and 110, respectively. As shown, the host computer 102 includes or is attached to a wireless unit 112 through which the communication links 108 and 110 are respectively established with a wireless unit 114 within the wireless keyboard 114 and a wireless unit 116 of the wireless mouse 106. The wireless unit 112 may be built into the chassis of the host computer 102 or added as an external peripheral device in the form of, for example, a "dongle". As an external peripheral device, the wireless unit 112 may either be interfaced to the computer 102 through a wired USB connection or by other available means such as the PS/2 keyboard connector.

[0037] During operation of the system 100, the wireless keyboard 0.104 and the wireless mouse 106 interact with the host computer 102 via wireless communication links 108 and 110. In particular, the wireless unit 112 receives keystroke and other data originating from the wireless keyboard 104 and the wireless mouse 106 over wireless communication links 108 and 110 and passes it to the host computer 102 in such a way that the host computer 102 is unaware of the existence of the wireless links 108 and 110.

[0038] As is described hereinafter, the wireless units 112, 114 and 116 of the present invention are configured to enable the communication links 108 and 110 to exhibit low latency and high reliability relative to conventional approaches employed using wireless peripheral devices. In addition, given that the wireless keyboard 104 and wireless mouse 106 will generally be battery powered devices, minimization of power consumption will typically be a primary design consideration. As a consequence, the wireless units 114 and 116 respectively incorporated within the wireless keyboard 104 and the wireless mouse 106 are disposed to cycle among various power-saving modes so as to conserve battery power and thereby substantially reduce the frequency of required battery replacement operations.

High-Level Architecture of Wireless Units

[0039] FIG. 2 illustratively represents a view of the layered architecture 200 of the wireless unit 112, it being understood that in the exemplary embodiment the wireless units 114, 116 are of essentially the same general architecture. As will be apparent to those skilled in the art, the layers depicted in FIG. 2 may be realized in hardware, firmware, or as software instructions stored on a computer-readable medium. Referring to FIG. 2, the unit 112 is seen to include a physical layer 204, a media access control (MAC) layer 208, and a device interface layer 212. As shown, the physical layer 204 interfaces with an antenna element 220.

[0040] The device interface layer 212 may be implemented as any known interface permitting the wireless unit 112 to interface with the host computer 102. Such a known interface may be designed to support communications between the host computer 102 and the wireless unit 112 in accordance with a standard communications protocol. For example, the device interface 212 may by designed to serve as a USB; PS2 or GPIO interface.

[0041] As is described below, the MAC layer 208 serves to control access to the wireless communication links 108, 110. That is, MAC layer 208 is responsible for enabling data to be transferred between the device interface 212 and the physical layer 204, and vice-versa. As shown, a portion of the functions associated with the MAC layer 208 in the exemplary embodiment are carried out by baseband hardware 260, but this is certainly not required. The physical layer 204 may comprise any structure or collection of elements functioning to transmit and receive bits of data over the wireless communication links 108, 110. As shown, the physical layer 204 includes a radio interface portion 250, which represents the registers and signals that are used to transfer messages between the physical layer 204 and the MAC layer 208. One potential implementation of the physical layer 204 is described in, for example, the above-referenced provisional application filed on even date herewith.

[0042] **FIG. 3** illustratively represents a block diagram of the wireless unit **112** of **FIG. 1** according to an exemplary embodiment of the present invention. As shown, the wireless unit **112** (also referred to herein as the host transceiver **112**) includes a CPU **302** that is coupled via a CPU bus (not shown) to ROM **304**, RAM **306**, a modem **308**, baseband hardware **309**, wake-up logic **310**, USB **312**, and an input/output (I/O) module **316**. The wakeup logic in the host device, although it is not generally required in this application, is an integral part of the logic implementation, which is the same in both the computer and peripheral input device. Also shown coupled to the modem **308** is an RF unit **314**, which is coupled to an antenna **220**. A power interface portion **330** provides power regulation to both analog and digital components of the host transceiver **112**. In one embodiment, the host transceiver **112** is realized as a single system-on-chip IC with protocol stack and application software being integrated in built-in mask ROM, but this is certainly not required.

[0043] In the exemplary embodiment, when the host transceiver **112** is transmitting information to one of the wireless devices **114**, **116**, the information is first encrypted, formatted and protected with a cyclical redundancy check (CRC) by the baseband hardware **309**. The modem **308** then receives and encodes (e.g., with differential binary phase shift key (BPSK) encoding) the formatted, encrypted and CRC protected information before it is up-converted for transmission by the RF portion **314**.

[0044] When receiving a signal from one of the devices **114**, **116**, the RF unit **314** down converts the received signal to an intermediate frequency (IF), and converts the IF frequency signal to a digital IF signal. The modem **308** then decodes the digital IF signal and checks the CRC to regenerate the original encrypted information, which is then decrypted by the baseband hardware **309**.

[0045] With respect to transmitting and receiving data, the modem **308** in the exemplary embodiment has four different modes: a high data rate (HDR) mode; a medium data rate (MDR) mode; a low data rate (LDR) mode and a spread mode. The HDR mode is the default mode, which can provide 150 kbps data transmission. The data rates for the MDR, LDR and spread mode are 30 kbps, 10 kbps and 13.64 kbps respectively. As described further herein, spread mode is used when there is interference from similar wireless device(s) (e.g., other host and device transceivers), and MDR is used when there is strong interference (e.g., narrowband interference) such as from citizen band (CB) radio.

[0046] In the exemplary embodiment, the host transceiver **112** is able to detect interference and switch to appropriate modes automatically. As a consequence, the host transceiver **112** provides highly reliable wireless data transfers even in an environment with multiple other wireless users. In the exemplary embodiment, the LDR mode is for European compliance purposes and may be omitted in transceivers intended for non-European markets. The data transmission rates of the exemplary embodiment (i.e., 150 kbps, 30 kbps, 10 kbps and 13.64), are more than sufficient for typical manual input devices (e.g., the keyboard **104** and mouse **106**), with very little or no perceptible latency.

[0047] The RF portion **314** in the exemplary embodiment operates to transmit and receive signals in accordance with the operating mode (i.e., the HDR, MDR, LDR and spread mode) of the modem **308**. In MDR mode for example, the RF portion **314** supports multiple selectable transmit frequencies so data may be selectively transmitted over a frequency channel that is substantially free from a strong narrowband interferer such as a citizens band (CB) radio.

[0048] In the exemplary embodiment, the I/O unit **316** of the host transceiver **112** is programmable to allow general-purpose I/O pins (not shown) of the host transceiver **112** to be selectively dedicated to a variety of interface communication protocols for communication with the host computer **102**. As shown in **FIG. 3** for example, the UO unit **312** is programmable so as to allow the following five I/O communication protocols to be selectively used with the general-purpose 10 pins: a general purpose input/output (GPIO) **318**, an intelligent interface controller (I 2C) path **320**, a universal asynchronous receiver/transmitter interface (UART) **322**, a USB interface **324** and a bidirectional synchronous serial interface (PS/2) 326.

[0049] The I^2C interface **320** is a two-wire, bi-directional serial bus which" provides a simple method of data exchange between devices. In the exemplary embodiment, the I^2C interface is used for downloading executable programs from external EEPROM to RAM **306** (e.g., to change functionality of certain aspects of the host transceiver), and/or reading configuration parameters that are stored in external EEPROM. In one embodiment, (e.g., when CPU clock is 12 MHz) the clock speed for the I^2C interface is software programmable from 200 Hz to 400 KHz (When CPU clock is 12 MHz). The host transceiver **112** may either be selected (e.g., via software) to be a master or a slave device.

[0050] The UART interconnect **322** provides serial communications between the host transceiver and terminal equipment (e.g., the host computer **102**). In one embodiment, the baud rate is software programmable from 250 bps to 330 Kbps. The universal Serial Bus (USB) interface **324** is a personal computer (PC) interconnect that can support simultaneous attachment of multiple devices. The USB module **312** in the present embodiment is realized by dedicated hardware and includes a USB function controller (not shown) and a full speed (12 Mb/s) USB transceiver (not shown). The PS/2 interface **326** is a two-wire (DATA, CLOCK), bi-directional synchronous serial interface. The PS/2 interface **326** in one embodiment includes two PS/2 interfaces: one for communications with the keyboard **104** and the other for communications with the mouse **106**.

[0051] In one embodiment, dedicated hardware in the host transceiver **112** is associated with one or more of the above described communication protocols. Although it is not necessary to dedicate hardware for I/O communications, latency may be substantially reduced over alternative CPU-driven software implementations.

[0052] Referring next to **FIG. 4**, shown is a block diagram depicting an exemplary embodiment of the wireless unit **114** of **FIG. 1**. As shown, the wireless unit **114** (also referred to herein as the keyboard transceiver **114**) includes a CPU **402** that is coupled to ROM **404**, RAM **406**, a modem **408**, baseband hardware **409**, RF unit **414** and an I/O module **416**, which in the exemplary embodiment, are substantially the same as the corresponding functional components within the host transceiver **112**. Also shown are wake-up logic portion **410** and a keyboard scan module **412**.

[0053] As shown, four exemplary communication protocols are available for the keyboard transceiver **114** to communicate with other devices: a general-purpose input/output (GPIO) **418**, an intelligent interface controller (I^2C) path **420**, a universal asynchronous receiver/transmitter interface (UART) **422**, and a keyboard interface **424**. These protocols and interfaces are made available to support various design options for the keyboard.

[0054] The keyboard interface **424** in one embodiment is realized with 20 GPIO ports that are dedicated to 20 corresponding columns of a keyboard's bare key switch contacts and 8 GPIO ports that are dedicated to 8 corresponding rows of the keyboard's bare key switch contacts. In addition, three optional high-drive open-drain outputs support up to three LED devices on the keyboard. In this embodiment, the I/O module **416** is programmed to switch the 28 GPIO ports dedicated to the keyboard to the keyboard scan module **412**.

[0055] The keyboard scan module **412** detects key presses and releases by receiving inputs from the keyboard interface **424** and performing debouncing and rollover handling. Debouncing is performed by keeping an image of the keyboard state in memory for the last N1 (e.g., three) scan cycles. In the exemplary embodiment, the keyboard scan module **412** does not report a state change until it persists for N1 scan cycles (the scan rate is approximately N2 (e.g., four) milliseconds per scan). As a consequence, the debounce time is approximately N1*N2 milliseconds. In one embodiment, the values of N1 and N2 may be changed via the host transceiver **112** by updating EEPROM of the host transceiver **112** with new values. The host transceiver **112** then sends the updated information to the keyboard transceiver **114** in a configuration message when communication is established with the host transceiver **112**.

[0056] In operation, each time a key press or release is detected, the keyboard scan module **412** provides key code (i.e., column and row) information to the CPU **402**, and the CPU **402** generates a message indicating the row and column. The message with row and column information is than transmitted from the keyboard transceiver **114** to the host transceiver **112**. The host transceiver **112** receives the message and then maps the row and column data into key codes, macros, or special functions.

[0057] After a period of inactivity, the CPU **402** instructs the wake-up logic portion **410**, as described further herein, to place the keyboard transceiver **114** in a sleep mode. The wake-up logic portion **410**, in combination with the power interface **430**, then effectively shuts down the CPU **402** by depriving it of a clock signal. In addition, a scan oscillator (not shown) in the keyboard scan module **412** is also deactivated so that the keyboard scan module **412** no longer carries out the keyboard scanning described above. Instead, the row inputs to the keyboard scan module **412** are logically ORed together so that any key-press will trigger the keyboard scan module **412** to restart the scanning process.

[0058] When the keyboard scan module **412** (operating in sleep mode) detects a key press, it sends a key press notification signal to the wake-up logic portion **410**, which in combination with the power interface **430**, brings the keyboard transceiver **114** out of sleep mode by reactivating the clock signal to the CPU **402**. Additional details of communications between the keyboard transceiver **114** and the host transceiver **112** when the keyboard transceiver **114** enters and exits sleep mode are described in the above-referenced provisional application filed on even date herewith.

[0059] Referring next to **FIG. 5**, shown is a block diagram depicting an exemplary embodiment of the wireless unit **116** of **FIG. 1**. As shown, the wireless unit **116** (also referred to herein as the mouse transceiver **116**) includes a CPU **502** that is coupled to ROM **504**, RAM **506**, a modem **508**, baseband hardware **509**, RF unit **514**, and the I/O module **516**, which in the exemplary embodiment, are substantially the same as the corresponding functional components within the keyboard transceiver **114**. Also coupled to the CPU **502** is a wake-up logic portion **510**, which is in communication with a mouse scan module **512**.

[0060] As shown, four exemplary communication protocols are available for the mouse transceiver **114** to communicate with other devices: a general-purpose input/output (GPIO) **518**, an intelligent interface controller (I^2C) path **520**, a universal asynchronous receiver/transmitter interface (UART) **522**, and a mouse interface **524**. These protocols and interfaces are made available to support various design options for the mouse.

[0061] In the exemplary embodiment, the mouse transceiver **116** receives, via a mouse interface **524**, motion signals from mouse motion transducer **510**, which is configured and positioned within the wireless mouse **106** to convert motion of the wireless mouse **106** into the motion signals.

[0062] Advantageously, the configuration of the mouse interface **524** in this embodiment is selectable to conform to the communication protocol of the mouse motion transducer **524**, which may vary depending upon the manufacturer and the type of technology (e.g., mechanical or optical position tracking) utilized by the wireless mouse **106**. Specifically, the I/O module **516** is programmable so that GPIO pins of the mouse transceiver **116** (not shown) are, dedicated for communications in accordance with the protocols utilized by the wireless mouse **106**.

[0063] In one embodiment for example, the mouse interface **524** is configured to communicate as an optical mouse interface according to a secure digital I/O communication protocol (SDIO), which uses an I^2C-like read/write sequencing scheme in which the mouse transceiver **116** operates as the master and the wireless mouse **106** as the slave. This configuration may be used, for example, to communicate with Agilent™ wireless mouse devices with SDIO interface capability including Agilent™ device No. ADNS-2030.

[0064] In another embodiment, the mouse interface **524** is configured to communicate as an optical mouse interface according to serial peripheral interface (SP1) protocols. In this embodiment, the mouse interface **524** includes four signals: a clock (CLK), a slave output (SO), a slave input (S1) and a slave select (CS), and the mouse transceiver **116** operates as the master while an optical sensor in the mouse **106** operates as the slave.

[0065] When the wireless mouse **106** utilizes mechanical position tracking technology, the mouse interface **524** includes one pair of quadrature signals for each of the X, Y, and Z axes, wherein the X and Y axes are associated with the translational movement of the wireless mouse **106** and the Z-axis is associated with movement of a roller ball of the wireless mouse **106**.

[0066] In the exemplary embodiment, the mouse scan module **512** operates in either a mechanical mode or an optical mode depending upon whether the wireless mouse **106** utilizes mechanical or optical position tracking. When operative in the mechanical mode, a single-axis state machine of a type described in the above-referenced copending patent application is executed by the mouse scan module **512** with respect to each of three perpendicular directional axes (i.e., the X, Y and Z axes). Operation in the mechanical mode also relies upon a button press detector (not shown), which preferably implements "debouncing" in the same manner as was described above with reference to the keyboard scan module **512**. Although the button press detector operates substantially identically in the mechanical and optical modes, in the exemplary embodiment the mouse scan module **512** does not execute state machines during operation in the optical mode. Instead, the mouse scan module **512** sends serial messages to the wireless mouse **106** and receives back position difference information or "deltas". These position deltas replace the counter values utilized during mechanical mode operation within the mouse position reports generated by the mouse scan module **512**.

Operation of Mouse and Keyboard Wireless Units
Transition Among Operative States

[0067] As mentioned above with reference to **FIG. 2**, the MAC layer **208** is responsible for formatting messages conveyed by the MAC layer **208** to and from the device interface **212** and the physical layer **204**. This aspect of the MAC layer **208** may be appreciated with reference to **FIGS. 6, 7** and **10**, which are event trace diagrams representative of various messages exchanged between the host wireless unit **112** and the keyboard/mouse wireless units **114, 116** under the control of their respective MAC layers **208**.

[0068] Referring initially to **FIG. 10**, an event trace diagram **1000** is provided which depicts the message sequences associated with normal operation of the keyboard/mouse wireless units **114, 116**. In addition, **FIG. 10** also illustrates a message sequence between the mouse wireless unit **116** and the host wireless unit **112** in the case in which a message sent by the mouse wireless unit **116** is lost or corrupted and re-transmitted.

[0069] Turning now to **FIG. 6**, there is shown an event trace diagram **600** representative of an event sequence pursuant to which the wireless unit **116** for the wireless mouse **106** transitions into and out of sleep state under the control of its MAC layer **208**. In the case in which the wireless unit **116** is awakened due to expiration of this time-out interval, the counters associated with each of the three directional axes are compared against a predefined value (e.g., 2). If none of the counters exceed this threshold, the time-out is restarted and sleep resumed; otherwise, a mouse report message is sent to the host transceiver **112** and these counters are reset to zero. As is shown in **FIG. 6**, once receipt of this mouse report message is acknowledged by the host transceiver **112**, the wireless unit **116** returns to sleep state. If an acknowledgment is not received, the mouse report message is discarded and the wireless unit **116** returns to sleep state.

[0070] **FIG. 7** illustrates, in a manner similar to **FIG. 6**, an event trace diagram **700** which represents an event sequence pursuant to which the wireless unit **116** for the wireless mouse **106** transitions into and out of sleep state under the control of its MAC layer **208** in the case in which messages are lost between the host wireless unit **112** and the wireless unit **1116**.

[0071] Consistent with the invention, the MAC layer **208** is also responsible for the overall transfer of data between the device interface **212** and the physical layer **204** and controls the transition of the applicable wireless unit **112, 114, 116** into and out of various operative states. Specifically, the MAC layer **208** of a given wireless unit is disposed to govern its transition among sleep, listen, backoff and pending states in the manner described hereinafter.

[0072] Turning now to **FIG. 13**, there is shown a state transition diagram **1300** representative of the manner in which transitions are made between the various states of a state machine executed by the MAC layer ***208**. In general, whenever one of the wireless units **114, 116** receives a message containing a long sequence (described below) identifying such unit **114, 116**, its MAC layer **208** checks the CRC to decide if the message is valid. A message received from the host wireless unit **112** (other than an ACK only) is acknowledged immediately. This acknowledgement may, but need not be, accompanied by data intended for the host wireless unit **112**. If a wireless unit **114, 116** sends data with or without a "piggyback" acknowledgement, the host wireless unit **112** is disposed to acknowledge the new data.

[0073] As is indicated by **FIG. 13**, if data is sent by a wireless unit **114, 116** and an acknowledgement is not immediately received following a short "ACK time-out" period, it is retransmitted by the wireless unit **114, 116** after waiting a "BACKOFF time-out" intended to break deadlocks caused by simultaneous transmissions. The "ACK time-out" period is selected to be roughly equal to the sum of (i) the round trip message transfer time between the applicable device (i.e., the wireless keyboard **104** or wireless mouse **106**) and the host computer **102**, and (ii) an allowance for processing time. In this regard an ACK time-out period of approximately 1.2 ms has been found to be appropriate for a number of anticipated implementations. It is observed that the time-out values described herein as being associated with the MAC layer **208**, including the above-described ACK time-out period, are dependent upon the data rate used for the relevant transmission. In particular, the values provided herein assume operation in a the HDR mode (i.e., 150 kb/s) discussed above. For transmissions occurring during operation in the MDR mode (i.e., 30 kb/s), the provided timeout values should be quintupled. Finally, the provided timeout values should be multiplied by a factor of 15 in connection with operation in the LDR mode (i.e., 10 kb/s).

[0074] In the exemplary embodiment the BACKOFF timeout is randomized between wireless units. Such randomization may be effected by, for example, utilizing the device ID of the applicable wireless unit in generating the period of the BACKOFF timeout. If a wireless unit is required to delay for the period of an additional BACKOFF timeout in connection with a given transmission, the duration of the BACKOFF timeout may be increased linearly in accordance with the device ID. Specifically, in an embodiment where N corresponds to the number of consecutive ACK timeouts for a given data packet, and IDMx is the device ID of the transmitting wireless unit, the duration of the BACKOFF timeout is given as BACKOFFmin+(N*f(IDx)). In this embodiment BACKOFFmin is approximately 0.5 ms, and f(IDx) is chosen such that the average extension per consecutive BACKOFF timeout increases by approximately 1 ms.

[0075] In order to avoid or minimize any confusion resulting from retransmission of the same data, each message preferably contains a one-bit "transmit sequence number" which is incremented (toggled) for each new transmission and maintained the same for a retransmission. To avoid similar difficulties from arising in connection with lost acknowledgements, a one-bit "receive sequence number" is incremented whenever a new packet is acknowledged by a wireless unit. This bit indicates the sequence number expected in the next packet from the transmitting wireless unit, and thus effectively serves as an acknowledgment of receipt of the prior packet. In other words, if a wireless unit successfully receives a packet numbered "zero", the receive sequence number is set to "I" in the next packet sent by such wireless unit. This receive sequence number of "1" is repeated in subsequent transmissions from the wireless interface device until it successfully receives another packet, which should have a transmit sequence number of "1".

[0076] In the case in which a first host/device wireless unit sends a packet of sequence "1" which is not received by a second device/host wireless unit, the receipt by the first wireless unit of a packet of receive sequence "1" (or an ACK timeout) transmitted by the second wireless unit indicates to the first wireless unit that its transmission of the sequence "1" packet was not received and it retransmits this packet. If, on the other hand, the packet of sequence "1" transmitted by the first wireless unit is received by the second wireless unit but the acknowledgment which it transmits is lost en route to the first wireless unit, the first wireless unit will either time out the acknowledgement (and retransmit) or receive another packet, which includes an acknowledgment in the form of the correct sequence number. However, any retransmission by the first wireless unit will generally be unnecessary, since the duplicate sequence number will be detected by the second wireless unit upon receipt of the retransmitted packet and the message re-acknowledged (and the duplicate, retransmitted packet discarded).

[0077] In the event that more than three retransmissions of a packet occur, in one embodiment the communication link between the applicable host/device wireless units is reset (i.e., the send sequence number and the receive sequence number are both set to "0"). Upon receipt of a valid reset message, the receiving wireless unit acknowledges it with a packet of receive sequence number "1" and send sequence number "0". It is observed that the term "three retransmissions" is intended to indicate that a set of three retransmissions of an original message have occurred, which results in the occurrence of four ACK timeouts and three BACKOFF timeouts. In one embodiment this consumes an average of approximately (4*1.2)+(3*(0.5+1)) ms or 9.3 ms, depending on the device ID. This interval provides a basis for the 10 ms duration of the LISTEN timeout, which is described below.

[0078] The receipt of an ACK by a host/device wireless unit concludes a present transaction between such unit and the device/host wireless unit with which it is in communication. In the absence of any new messages to transmit, the wireless unit **112** listens for unsolicited (random access) messages from the wireless units **114**, **116** following receipt of an ACK. In contrast, the wireless units **114**, **116** enter a sleep mode following receipt of an ACK. In the case in which the last ACK of a transaction is lost in transit following transmission by a keyboard/mouse wireless unit **114**, **116**, the host wireless unit **112** retransmits the previously received message following expiration of the ACK timeout period. If the keyboard/mouse wireless unit **114**, **116** enters sleep mode as soon as it transmits this "lost" ACK, it will not receive the retransmission from the host wireless unit **112** and the host wireless unit **112** will be unaware that its message has been successfully received. In view of this possibility, the keyboard/mouse wireless unit **114**, **116** is configured to wait a short period in LISTEN mode prior to entering sleep mode so as to maximize the likelihood that it will receive any possible retransmission from the host wireless unit **112**. As noted above, in one embodiment any message/acknowledgement transaction should complete in less than approximately 10 ms. Therefore, when a keyboard/mouse wireless unit **114**, **116** sends an ACK only message, it waits until expiration of a LISTEN timeout period of 10 ms before entering sleep mode. This effectively ensures that any retransmissions from the host wireless unit **112** will be received by the keyboard/mouse wireless unit **114**, **116** prior to expiration of the LISTEN timeout period.

[0079] In the exemplary embodiment, packets transmitted by the keyboard/mouse wireless unit **1114**, **116** are of the following general format:

[0080] 1. Short and long preamble sequences (16 bits)

[0081] 2. Transmit sequence number (1 bit)

[0082] 3. Receive sequence number (1 bit)

[0083] 4. Data present (=0)/acknowledgement only (=1) (1 bit)

[0084] 5. Reserved bits set to zero (1 bit)

[0085] 6. Device indication (3 bits, 0=keyboard, 1=mouse, other values reserved for future use)

[0086] 7. Mouse or keyboard data (24 bits) All zeros reserved as reset indication

[0087] 8. 8 bit CRC over the entire message excluding preamble.

TABLE I

Format for packet sent from keyboard/mouse transceiver										
	Header							Payload		
Preamble	T	R	ACE	RSV	PL-Length	Device Indicator	Header-CRC	MAC Payload	MAC CRC	Payload CRC
16	1	1	1	1	7	3	8	0 – $(2^7 - 1)*8$		16

[0088]

TABLE II

Format for packet sent from keyboard/mouse transceiver (no payload case)							
	Header						
Preamble	T	R	ACE	RSV	PL-Length	Device Indicator	Header-CRC
16	1	1	1	1	7	3	8

[0089]

TABLE III

Format for packet sent from host transceiver (payload case)									
	Header								
Preamble	T	R	ACK	RSV	PL-Length	Device Indicator	Header-CRC	MAC Payload	Payload CRC
16	1	1	1	1	7	3	8	0 – $(2^7 – 1)*8$	16

Radio Interface and Transmission Rate Selection

[0090] As was mentioned above, the radio interface **250** (**FIG. 2**) is representative of the set of registers and signals used in transferring messages between baseband hardware **260** within the MAC layer **208** and the remainder of each wireless unit. In the exemplary embodiment the baseband hardware **260** within the keyboard/mouse wireless units **114**, **116** performs encryption/decryption, CRC generation and checking, serialization/de-serialization, and also provides an interface to the RF units **414**, **514**.

[0091] In the exemplary embodiment the radio interface **250** within the keyboard/mouse wireless units **114**, **116** facilitates performance of at least the following functions: (i) enabling of the transmitter within the RF unit **414**, **514**, (ii) enabling of the receiver within the RF unit **414**, **514**, (iii) sending a message to the RF unit **414**, **514**, (iv) receiving a message from the RF unit **414**, **514**, (v) link quality assessment, (vi) selection of the rate used within the RF unit **414**, **415**, (vii) selection of the channel used within the RF unit **414**, **415**, (viii) control of output power of the transmitter within the RF unit **414**, **415**, (ix) setting the long sequence of the receiver within the RF unit **414**, **415**, and (x) setting the long sequence of the destination wireless' unit within the transmitter of the RF unit **414**, **415**.

[0092] Referring to **FIG. 8**, an event trace diagram **800** depicts the enabling of the transmitter/receiver within the RF units **414**, **514** using single-bit signals under control of the MAC layer **208**. As is indicated by **FIG. 8**, when the wireless unit **114**, **116** enters sleep mode, it disables both the transmitter and the receiver within its RF unit **414**, **514**.

[0093] Message Transmission

[0094] In the exemplary embodiment the MAC layer **208** initiates the sending of a message by loading the body of the message into a set of registers within the radio interface **250** and signaling "send" to the baseband hardware **260**. In particular; prior to asserting "send" the MAC layer **208** loads the following information into registers within the radio interface **250**:

[0095] 1. Long sequence of destination (16 bits)

[0096] 2. Header (8 bits)

[0097] 3. Pointer to message (16 bits)

[0098] 4. Power Level (2 bits)

[0099] 5. Data Rate (1 bit)

[0100] 6. Channel (3 bits)

[0101] 7. Length of message (which asserts "send").

[0102] The "long sequence" is a 16 bit, bit sequence that is generated from the unit's 1-bit device ID. By expanding the number of bits used to represent the ID, it is possible to distinguish between valid ID's received without bit errors and ID that are invalid because a bit error occurred during transmission. The "header" (8 bits) comprise, transmit and receive sequence number bits, the "ACK only" bit, two zero bits, and the 3-bit device type The "power level" is the RF transmitter's power level. It can be adjusted with four possible settings. Higher power for better range and reduced bit errors, lower power to conserved battery life.

[0103] Prior to initiating the process of sending a message, the MAC layer **208** calculates the proper long sequence of the destination device by writing the device ID of such device into a register within the radio interface and reading back the long sequence. In the case of the host wireless unit **112**, the MAC layer **208** is configured to track both of the keyboard/mouse wireless units **114**, **116** and maintain separate long sequences for each of them. The MAC layer **208** of the host wireless unit **112** also calculates a long sequence for the pairing device ID when the unit **112** is operative in a dynamic pairing (DP) mode (discussed below).

[0104] When "send" is asserted, the baseband hardware **260** continues the transmission process by sending the short sequence, which is a predetermined fixed training sequence used to bit synchronize the receiving modem to the transmitting modem, the specified long sequence, followed by the header and the body of the message itself. If the header specifies a device type of keyboard, the message portion is encrypted prior to transmission. Finally, the CRC is appended to the transmission.

[0105] Message Reception

[0106] Upon enabling of the receiver of the RF unit **414**, **514**, the baseband hardware **260** listens for a message with a long sequence matching the long sequence of the applicable keyboard/mouse wireless unit **114**, **116**. Prior to performing this enabling operation, the MAC layer **208** calculates its "own" long sequence by writing the device ID of the applicable keyboard/mouse wireless unit **114**, **116** into a register within the radio interface **250**. Except during pairing (discussed below), this need only be done once; during pairing, the reserved pairing device 1D is instead written to the radio interface **250**. The MAC layer **208** also sets a message pointer register (16 bits) in order to inform the baseband hardware **260** of the location in which the received message should be placed.

[0107] Once a matching long sequence is detected, the baseband hardware **260** receives the ensuing header and message into a header register and a message buffer (not shown), respectively. In the host wireless transceiver unit **1.12**, the message is first decrypted if the header specifies a device type of keyboard. The baseband hardware **260** then checks the received CRC. If the CRC is valid, it asserts "data ready" to the MAC layer **208**. Conversely, the baseband hardware **260** must not present data (i.e., assert "data ready") to the MAC layer **208** if the CRC is invalid, although the data may already be present within the message buffer. The MAC layer **208** is configured to respond as quickly as possible to the receipt of a data message with a message in the reverse direction indicating acknowledgement.

[0108] Data Rate Selection

[0109] As was mentioned above, except where prohibited by regulation communication occurs between wireless units in the HDR mode (i.e., at 150 kb/s) by default. In order to provide more robustness in the presence of severe interference, the applicable RF units are capable of falling back to operation in the MDR mode (i.e., 30 kb/s). In the exemplary embodiment, 5 channels are available for hopping during operation in the MDR mode. In European jurisdictions, the LDR mode is employed in order to comply with the pertinent regulations. Fallback from operation in the HDR mode to the MDR mode and channel selection are controlled by the MAC layer **208**. This control is facilitated by a received signal strength indication ("RSSI") provided by the RF unit, which is asserted in the presence of strong interference within the frequency bands of interest.

[0110] Turning now to **FIG. 9**, there is shown a state transition diagram **900** representative of the manner in which the MAC layer **208** changes the data rate and channel of the wireless unit in which it is disposed. In the exemplary embodiment the data rate and channel of the RF unit of a wireless interface device are changed, if necessary, immediately prior to transmission of a data packet. These changes are based upon the current RSSI status and the success or failure of the previous transmission by the RF unit. When a change in channel is required, the channel sequence followed is 0-3-1-4-2-0. It has been found that adhering to a fixed sequence of this type minimizes the searching required to re-locate a partner wireless unit following a channel change. Since an interfering signal may straddle adjacent channels, it is desirable to avoid hopping to an adjacent channel; and the sequence above (and its mirror in time) is the only such sequence which prevents this from occurring.

[0111] As is indicated by **FIG. 9**, during operation at the medium rate the selected channel is only changed in response to link failure (which presumably occurs due to interference). Since the host wireless unit **112** rarely initiates a transaction with a keyboard/mouse wireless unit **114**, **116** (i.e., most data traffic is inbound to the unit **112**), while operative in medium rate mode it is possible for it to "sit" on a bad channel as it is unlikely to receive information indicating that the channel is bad. In order to avoid this situation, the host wireless unit **112** is configured to change channels every 1 to 2 seconds during operation in medium rate mode. Since each keyboard/mouse wireless unit **114**, **116** is likely to be in sleep mode when this change in channel occurs, each will generally experience an ACK timeout following transmission of its next message. This timeout will also result in a change in channel. It is noted that in the case of the wireless unit **114** of the keyboard **104**, the ACK timeout will cause it to reset encryption; accordingly, the host wireless unit **112** must likewise do so.

[0112] Referring again to **FIG. 9**, during operation of a wireless unit at the low data rate it is seen that the selected channel changes after each successful transmission. During operation at both the low and medium data rates, the channel number is reset to zero whenever the communication link is established; otherwise, whenever a transition to the medium data rate occurs, the channel last used is selected. This approach is intended to maintain channel synchronization between the wireless units at either end of the communication link. Except during operation in low data rate mode, in exemplary embodiments hardware encryption is reset whenever the channel or rate is changed; this will generally be preceded by a link reset message exchange in order to ensure timing synchronization.

[0113] Device Message Format

[0114] Referring now to Table IV below, descriptions are provided of the messages transmitted from the keyboard/mouse wireless units **114**, **116** to-the host wireless unit **112**, and vice-versa. As may be appreciated by reference to Table IV, each device message contains a payload of 24 bits. The bits in each message payload are utilized as follows:

[0115] Mouse report: 5 bits indicating the state of the buttons, and 6 bits for each of 3 axes containing the delta position in that axis since the last report. MS (most significant) bit is always 1.

[0116] Keyboard report: 1 bit indicating key pressed or released, 5 bits specifying the column of the keypress, and

3 bits specifying the row. The MS bit of the report is always 0. If a scroller is present, motion is reported as if the scroller were a mouse axis in a separate field. This message is always encrypted.

[0117] Reset request: This message is comprised of all zeros. The wireless keyboard does not encrypt this message, since it is sent when the keyboard and transceiver may be out of synchronization.

[0118] Pairing accept: MS bits=010, LS (least significant) bits contain device ID.

[0119] GPIO data: MS bits=011, middle byte specifies group, low byte specifies value. The section below concerning "GPIO Pins" includes additional pertinent information.

TABLE IV

DIRECTION Host <> Dev	NAME	DESCRIPTION	Format (MSb <---> LSb, 24 bits)																							
			23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
<----->	Link Reset	Reset MAC layer resync	0	0	0	0	0				0								0							
------->	Device Reset	Reset device state (keys down, etc.)	0	0	0	0	0				0								1							
------->	Shut-down	Go to sleep	0	0	0	0	0				0								2							
------->	Keep Alive	Poll	0	0	0	0	0				0								3							
------->	Test	Enter test mode	0	0	0	1	0				Test Number								Test Parameter							
<-------	Key-board Report	Report keypress/ release	0	0	1	0	0					Scroller Motion (if present)						Up / Dn	Row			Column				
N/A	N/A	Future use	0	0	1	1	Undefined																			
<----->	Pairing	request/ accept	0	1	0	0	0									Sender Device ID										
------->	Optical Mouse	Write mouse register	0	1	0	1	0				Register #								Data							
<------>	GPIO	Read/write GPIO pins (to device, value to TxRx)	0	1	1	0	0			R / W	Group								Value							
------->	Config-Set	Write config. parameter	0	1	1	1	0				Register #								Data							
<-------	Mouse Report	Report buttons/ motion	1	Btn State <-> 40					X Motion						Y Motion						Z Motion					

Operational Modes and Pairing Procedure

[0120] The wireless units **112**, **114** and **116** are designed for operation in either one of two modes, determined at the time of manufacturing; specifically, operation may occur in either a "dynamically paired" (DP) mode or in an "out of the box" or (OOB) mode. The DP mode is designed for business or commercial situations where multiple users may have similar devices in close proximity to each other. As is discussed below, the keyboard/mouse wireless unit **114**, **116** randomly generates an ID code, which is transferred to the host wireless unit **112** at pairing time. Also at pairing time, the keyboard/mouse wireless unit **114** and **116** learn the ID code of the host wireless unit **112**, which is used on all transmissions from the keyboard/mouse wireless unit **114** and **116**.

[0121] The OOB mode is intended for consumer usage environments in which multiple devices are unlikely to be located closely together. This mode does not require performance of a pairing process, and thus a keyboard/mouse wireless unit **114**, **116** is ready to use as soon as batteries are inserted into the wireless keyboard **104** or wireless mouse **106** in which it is disposed. In this mode, all mouse wireless units **114** use the same fixed ID code, and all keyboard wireless units **116** share a single (different) fixed ID code.

[0122] As may be appreciated from the above, each wireless unit **112**, **114**, **116** is either pre-assigned a device ID or are assigned a dynamically generated device ID at pairing. With the exception of a few reserved sequences (e.g., all "0" or all "1"), in the exemplary embodiment all 11-bit device IDs are valid. If a device is in DP mode, at pairing time it generates a random 11-bit ID in hardware upon powering-up. This device II) is passed through a hardware block described in the above-referenced copending provisional patent application, which converts the device ID into a 16-bit long sequence which is incorporated within messages intended for receipt by the applicable wireless unit. Prior to enabling the receiver within its RF unit, a wireless unit **112**, **114** and **116** writes its 16-bit long sequence to its radio interface. During operation, the receiver listens for messages having addresses containing this long sequence.

[**0123**] Whenever a message is transmitted a wireless unit **112**, **114**, **116**, a long sequence prefix identifies the ID code of the intended recipient In the DP mode, the host wireless transceiver unit **112** does not possess a priori knowledge of the device ID of the keyboard/mouse wireless unit **114**, **116**. Rather, during operation in DP mode a "pairing" operation is performed pursuant to which a device ID is dynamically generated by the keyboard/mouse wireless unit **114**, **116** and

[**0124**] communicated to the host wireless unit **112**. This operation is performed following each loss of power within the keyboard/mouse wireless unit **114**, **116** (e.g., whenever the batteries of a unit **114**, **116** are changed).

[**0125**] In one embodiment of the OOB mode, each transceiver is identified by a predefined address. Specifically, a host transceiver is assigned TR-DEFAULT as an address, a keyboard transceiver is assigned KB-DEFAULT as an address, and a mouse is assigned M-DEFAULT as an address. Following completion of a successful pairing operation between a host and device transceiver, the paired transceivers will have unique addresses. In addition, in this embodiment a host transceiver assumes its unique address when communicating with a paired device transceiver. However, the host transceiver will continue to use TR-DEFAULT during communication with unpaired device transceivers.

[**0126**] In the case in which patch EEPROM is included within the host/device transceivers, in one embodiment all will have unique addresses. In the case in which the host/device transceivers lack an EEPROM, in one embodiment the host transceiver uses the preamble corresponding to the TR-DEFAULT address. In the case in which the host/device transceivers include an EEPROM, the host transceiver uses the preamble corresponding to its unique address.

[**0127**] **FIG. 12** is an event trace diagram **1200** representative of the messages exchanged during a pairing operation involving a keyboard/mouse wireless unit **114**, **116** (a "device") and the host wireless unit **112**. As shown, the pairing operation is initiated by the manual push of a predefined button of the host wireless unit **112** followed by the pressing of a predefined button of the keyboard **104** or mouse **106** associated with the device within a few seconds. When the host wireless unit **112** is incorporated within a dongle (not shown) attached to the host PC **102**, a dedicated button may be provided on the dongle for use during pairing. Success of the pairing operation is evidenced by proper operation of the device (e.g., by keystrokes or mouse clicks being processed by the host PC following receipt by the host wireless unit **112**). If the pairing operation fails, both sides continue to attempt to pair until success or expiration of a predefined number of attempts (e.g. 1000). If the timeout period expires, the device goes to sleep until the pairing button of the keyboard **104** or mouse **106** associated with the device is pushed again.

[**0128**] As is indicated by **FIG. 12**, when the predefined button activating pairing operation of the host wireless unit **112** is pressed, the host wireless unit **112** begins transmitting "pairing request" messages which contain the transceiver ID code of the host wireless unit **112** and which are addressed to a reserved ID code (e.g., all "is"). When the predefined button of the keyboard **104** or mouse **106** attached to the device is pressed, the device temporarily assumes the reserved ID and listens for pairing requests from the host wireless unit **112**. If the device successfully receives a request, it responds with an ACK containing a pairing accept message to the transceiver ID code. This message contains the actual device ID code of the transmitting device.

[**0129**] The host wireless unit **112**, between issuing pairing request messages, listens for incoming messages. If it receives a pairing accept message from the device, it remembers the ID code of its new partner and acknowledges it. Once, the acknowledgement is received at the device, the device assumes its "rear' identity; that is, it begins sending and receiving messages on the basis of its actual device ID. Once the device has assumed its actual identity, it transmits a reset message to the host wireless unit **112**. If the reset message is acknowledged by the host wireless unit **112**, the applicable communication link **108**, **110** is considered established and normal operation ensues.

[**0130**] When the pairing button associated with the host transceiver is pressed, in the exemplary embodiment the host transceiver transmits pairing request messages periodically (every 50 ms in the case of HDR), using a fixed PAIRING-PREAMBLE. The pairing request message will generally contain the unique address of the host transceiver (32 bits), and host transceiver preamble (16 bits). When the pairing button triggering the keyboard/mouse transceiver is pressed, it will listen to pairing request messages for a pairing interval (55 ms in the case of HDR) using the fixed PAIRING-PREAMBLE. When this period expires, the keyboard/mouse transceiver checks whether there are any user input events. If there are user events, the keyboard/mouse transceiver transmits them for (2× period−pairing interval) (2×50−55=45 ms for HDR). If there are not any user inputs, the keyboard/mouse transceiver immediately returns to the pairing process. If the keyboard/mouse transceiver successfully receives a pairing request, it responds with an ACK containing a pairing accept message using the preamble of the host transceiver. This message contains the unique address (32 bits) of the keyboard/mouse transceiver. If the host transceiver hears the pairing accept message from the keyboard/mouse transceiver, it remembers the address of the keyboard/mouse transceiver and acknowledges the pairing accept message. When this acknowledgement is received at the keyboard/mouse transceiver, the keyboard/mouse transceiver assumes the its new address.

Device Configurability Options

[**0131**] Referring now to **FIG. 11**, there is shown a computer system **1100** in accordance with the present invention to which reference will be made in describing one manner in which various parameters of wireless units operative within the system **1100** may be configured upon establishment of radio communication links between such units. As shown, the system **1100** includes a host wireless unit **1112** of a host PC **1102**, a wireless unit **1114** of a wireless keyboard **1104**, and a wireless unit **1116** of a wireless mouse **1106**.

[**0132**] In the embodiment of **FIG. 11**, costs of implementing the system **1100** are minimized by designing the host wireless unit **1112** to incorporate an EEPROM **1134** as well as a host transceiver module **1130**. In this regard the host transceiver module **1130** is disposed to implement all of the above-described functionality of the host wireless unit **112**. In addition, the EEPROM **1134** stores configuration options for each of the wireless units of the system **1100**; that is, configuration information is stored for the host transceiver module **1130** and keyboard/mouse wireless units **1114**, **1116**. By taking advantage of the two-way radio links between the host transceiver module **1130** and keyboard/mouse wireless units **1114**, **1116**, the parameters stored within the EEPROM **1134** may be distributed to the keyboard/mouse wireless units **1114**, **1116** upon the establishment of radio communication within the system **1100**.

[**0133**] In certain embodiments the keyboard/mouse wireless units **1114**, **1116** each include a small amount of writable non-volatile memory (e.g., 4 KB). Alternatively, the keyboard/mouse wireless units **1114**, **1116** do not include writable non-volatile memory, and power-up in a fixed state defined only by hardware inputs and built-in defaults. Since requiring multiple pins for configuration is cumbersome and expensive, in the exemplary embodiment each keyboard/mouse wireless unit **1114**, **1116** uses only one pin for configuration input to specify operation in either the DP or OOB mode. Upon power-up of a keyboard/mouse wireless unit **1114**, **1116**, various operational parameters are set to the default values stored within corresponding locations of its writable non-volatile memory or registers.

[**0134**] Once a radio link has been established between the host transceiver module **1130** and a **30** keyboard/mouse wireless unit **1114**, **1116**, the host transceiver module **1130** reads the EEPROM **1134** and identifies those operational parameters of the keyboard/mouse wireless units **1114**, **1116** with respect to which the default values should be overridden. For each of these identified parameters, the host transceiver module **1130** sends a configuration message to the keyboard/mouse wireless unit **1114**, **1116**. Each configuration message includes a parameter ID uniquely identifying a register or the location within the non-volatile memory of the keyboard/mouse wireless unit **1114**, **1116**, as well as a parameter value to be stored in such location. As mentioned above, the value of each parameter is initialized upon power-up of the keyboard/mouse wireless unit **1114**, **1116** to a default value; however, the sending of a configuration message permits the default value to be overridden with a desired value appropriate for the intended application and/or system environment. In the exemplary embodiment the keyboard/mouse wireless unit **1114**, **1116** does not attempt to validate or otherwise check these values; rather, it simply writes the selected register or memory location and proceeds.

[**0135**] In summary, for each parameter to be changed in a keyboard/mouse wireless unit **1114**, **1116**, the host wireless unit **1112** issues a configuration message containing the parameter ID and the desired value. These values simply replace the defaults until the keyboard/mouse wireless unit **1114**, **1116** loses power. Upon again becoming energized, the keyboard/mouse wireless unit **1114**, **1116** re-establishes its radio link with the host wireless unit **1112**, and the parameter overrides are retransmitted.

[**0136**] If no parameter overrides are required and the system **1100** is operating in OOB mode, then no EEPROM **1134** is required within the host the host wireless unit **1112**. However, the absence of the EEPROM **1134** is generally not a sufficient basis upon which to assume that operation in the OOB mode is intended, as the apparent absence of EEPROM **1134** may in fact be the result of a failure. In order to detect this situation, one configuration input is used at the hardware pin level. Specifically, pulling up this pin with a resistor **1140** indicates that EEPROM **1134** is not present.

[**0137**] As the host wireless unit **1112** and the keyboard/mouse wireless unit **1114**, **1116** each have built-in defaults for all parameters, only variations need be stored within the EEPROM **1134**. Accordingly, in implementations of the system **1100** in which no changes are required to be made to these built-in defaults, no EEPROM **1134** is required. That being said, if the system **301100** is intended to be used in DP mode, it will necessary for some provision to be made for the host wireless unit **1112** to remember its pairings when the host PC **1102** is turned off and the host wireless unit **1112** loses power.

[**0138**] In the embodiment of **FIG. 11**, it is necessary for each keyboard/mouse wireless unit **1114**, **1116** to know in which mode (DP or OOB) it is to be operative upon powering up. Since in this case only two possible operational modes exist, only one bit of configuration information need be provided in order to select between modes. By providing the option of adding a mode selection resistor **1150**, **1152** to each the keyboard/mouse wireless units **1114**, **1116**, providing this configuration information to each device may be achieved at a “cost” of only one resistor per device and obviates the need to provide additional pins. In an exemplary embodiment the presence of the resistor **1150**, **1152** results in the keyboard/mouse wireless unit **1114**, **1116** becoming operative in the OOB mode (i.e., the device uses a single static device ID for communicating with the host wireless unit **1112**. If the resistor **1150**, **1152** is absent, then the keyboard/mouse wireless unit **1114**, **1116** elects a random device ID and expects the pairing procedure discussed above to be followed.

[**0139**] In order to provide positive confirmation of the validity of the contents of the EEPROM **1134**, the records for each wireless unit **1112**, **111** are protected by checksums which are verified each time the host wireless unit **1112** powers up. As discussed above, in order to resolve the ambiguity, which may exist if the EEPROM **1134** is not accessible upon the host wireless unit **1112** powering on (i.e., either the EEPROM **1134** is present but defective or is simply not present), the resistor **1140** is used to indicate whether or not the EEPROM **1134** should be present. If the resistor **1140** is present, no attempt is made to access an EEPROM **1140** and the system **1100** operates utilizing its default values. If the resistor **1140** is absent, then the EEPROM **1134** must be present and checksum tests are performed upon the records of the EEPROM **1134**.

[**0140**] Referring now to Table V, a list of exemplary default values and ranges is provided for various operational parameters (or, equivalently, “options”) of the keyboard wireless unit **1114**. For each operational parameter that is to bet set at something other than its default value, a corresponding option value is transferred from the host wireless unit **1112** to the keyboard wireless unit **1114** once a communication link has been established between the units **1112**, **1114**. It is observed that a set of keyboard-related options are also implemented by the host wireless unit **1112** (see Table IV below), and thus need be transferred to the keyboard wireless unit **1114**.

TABLE V

Keyboard Configuration Options

Option #	Description	Default Value	Min Value	Max Value
K1	Paired/Out of Box (OOB) Mode	OOB	Paired	OOB
K3	Scan Rate (# of scans for debounce)	5	1	7
K4	Scan Time (ms between scans)	4	1	7
K6	"Same Keys Down" Timeout (seconds)	2	0 (never)	63
K7	Phantom Timeout (seconds)	20	0 (never)	63
K8	Keep-Alive (Out of Range Detection) Interval (seconds)	0 (Do not wake up)	0 (Do not wake up)	255

[0141] Table VI provides a list of exemplary default values and ranges for various options of the mouse wireless unit **1116**. For each operational parameter that is to bet set at something other than its default value, a corresponding option value is transferred from the host wireless unit **1112** to the mouse wireless unit **1116** once a communication link has been established between the units **1112**, **1116**. A large percentage of an optical mouse's battery life is typically consumed by the mouse's optical sensor. To conserve battery life, the sensor operation is suspended periodically after movement of the mouse is stopped. The suspension duration is increased in a stepwise fashion as the time since the last movement is increases. In the preferred embodiment there are four steps. S0, S1, S3 and S4. The duration of each step and the and the duration of the suspension during each step is configurable.

[0142] It is observed that a set of mouse-related options are also implemented by the host wireless unit **1112** (see Table VII below), and thus need be transferred to the mouse wireless unit **1114**.

TABLE VI

Mouse Configuration Options

Option #	Description [unit]	Default Value	Min Value	Max Value
M1	Paired/Out of Box (OOB) Mode	OOB	Paired	OOB
M3	Button Scan Rate [# of scans for debounce]	5	1	7
M4	Button Scan Time [ms between scans]	4	1	7
M5	Mouse Type	Mech.	Mech.	Optical
M6	S0 → S1 Timeout [ms]	200	0 (never)	255
M7	S1 Sample Rate [ms]	10	1	255
M8	S1 → S2 Timeout [sec]	60	0 (never)	255
M9	S2 Sample Rate [ms]	65	1	255
M10	S2 → S3 Timeout [10 sec]	120	0 (never)	255
M11	S3 Sample Rate [ms] (0 implies button press required to wakeup)	0	0	255
M12	Keep-Alive (Out of Range Detection) Interval (seconds)	0 (Do not wake up)	0 (Do not wake up)	255

[0143] Table VII provides a list of exemplary default values and ranges for various options of the host transceiver module **1130**. In the exemplary embodiment there exist three logical groups of options processed by the host transceiver module **1130**. The first and second option groups (i.e., Group I and Group 2) relate to the operation of the keyboard/mouse wireless units **1114**, **1116**, but are processed locally by the host transceiver module **1130**. The third logical group (i.e., Group 3) of Table VII consists of options pertinent to operation of the host transceiver module **1130** itself.

TABLE VII

Host Transceiver Configuration Options

Option #	Description [unit]	Default Value	Min Value	Max Value
Group 1				
TK1	Keyboard Present?	Yes	No	Yes
TK2	Keyboard Device ID (high byte)	OOB value (H)		
TK3	Keyboard Device ID (low byte)	OOB value (L)		
TK4	Battery Levels to Report	2	0 (no report)	7
TK5	Use Alternate Scan Code Table?	No	No	Yes
TK6	Scroller Type	Volume Control	Volume Control	Scroll Keys
TK100–TK260	Alternate Scan Code Table	—		
Group 2				
TM1	Mouse Present?	Yes	No	Yes
TM2	Mouse Device ID (high byte)	OOB value (H)		
TM3	Mouse Device ID (low byte)	OOB value (L)		
TM4	Optical Mouse Frame Rate (high limit) (high byte)	1500 (H) (=5)	0	255
TM5	Optical Mouse Frame Rate (high limit) (low byte)	1500 (L) (=220)	0	255
TM6	Optical Mouse Frame Rate (low limit) (high byte)	1500 (H) (=5)	0	255
TM7	Optical Mouse Frame Rate (low limit) (low byte)	1500 (L) (=220)	0	255
TM8	# of Mouse Buttons	3	0	5
TM9	Counts per (0.1) Inch (multiple of 10 cpi; 20 = 200 cpi)	20?	0	255
TM10	Battery Levels to Report	2	0 (no report)	7

TABLE VII-continued

Host Transceiver Configuration Options

Option #	Description [unit]	Default Value	Min Value	Max Value
TM11	PS/2 Commands	Standard	Standard	BTC
TM100	Optical Mouse Init Command Count	0	0	15
TM101	Init Command 1 Register	—	0	255
TM102	Init Command 1 Value	—	0	255
TM103 up	Rest of Init Commands (2 options per command, up to a maximum of TM130)	—	0	255
Group 3				
TT1	Transceiver Device ID (high byte)	OOB value (H)		
TT2	Transceiver Device ID (low byte)	OOB value (L)		
TT3	European Operation (low rate hopping)	No	No	Yes
TT4	Encryption Key	—		

[0144] GPIO Pins

[0145] In order to enhance the potential for configurability of the wireless units **1114, 1116**, each may include a number of external pins defined as general purpose I/O (GPIO). Electrically, each of these pins will generally be implemented as an open drain output with the ability to be read back as an input if an associated output register contains a "1" bit. Upon power-up, the device wireless unit **1114, 1116** unit initializes its GPIO pins to "1" values and thereafter is not involved in changing their values. For reference purposes, GPIO pins are grouped into sets of eight, which are manipulated in parallel. Each group of eight is assigned a group number.

[0146] Under certain circumstances the host wireless unit **112** may request to set or read a group of GPIO pins of a wireless unit **1114, 1116**. To this end the host wireless unit **1112** conveys such a request to the device wireless unit **1114, 1116** by way of a GPIO read or GPIO write message containing an identification of the group number. In the case of a GPIO write message, the value to be written is also provided. Upon receipt of a GPIO read message, the device wireless unit **1114, 1116** responds with a GPIO data message containing the requested data. It is the responsibility of the host wireless unit **1112** to write a "1" to any input bit before it is read.

Device Customization and Application Development

[0147] In addition to enabling the wireless units **114, 116** to be flexibly configured in the manner described in the previous section, in one aspect the present invention further contemplates that the operation of the wireless units **114, 116** be amenable to customization in view of the requirements of various applications. To this end, the software executing on the wireless units **112, 114, 116** has been designed to incorporate various "hooks" in order to allow certain parameters adjusted. Such hooks are also intended to allow portions the software to be extended or replaced by supplementary software included within an inexpensive external serial "patch" EEPROM of the general type described above with reference to **FIG. 11**.

[0148] Referring to **FIG. 22**, a high-level representation is provided of a system **2200** comprised of wireless units incorporating EEPROM patches in accordance with one aspect of the present invention. In particular, the system **2200** includes a host wireless unit **2212** incorporating transceiver software within a ROM **2222** and transceiver patch software within an EEPROM **2232**. The system **2200** further includes a keyboard wireless transceiver **2214** containing a ROM **2224** in which is stored keyboard software and an EEPROM **2234** in which is stored keyboard patch software. Finally, the system **2200** also includes a mouse wireless transceiver **2216** configured with a ROM **2224** incorporating mouse software and an EEPROM **2236** incorporating mouse patch software.

[0149] In general, the host transceiver **2212** and device transceivers **2214, 2216** are ROM-based designs. That is, the bulk of the program code stored within these transceivers is normally executed from ROM. However, the inclusion of serial EEPROM within one or all of the transceivers **2212, 2214** and **2216** facilitates a patching procedure allowing certain default operational parameters to be changed at startup and limited changes to be made to the operating software of the transceiver.

[0150] **FIG. 23** is a flowchart representative of certain aspects of the operation of the system **2200**. As shown in **FIG. 23**, upon powering-up the processor (not shown) within each transceiver **2212, 2214, 2216** initializes critical hardware and software then checks the I^2C bus to which it is connected for the presence of an external EEPROM. If an EEPROM is present, the processor reads the first few EEPROM bytes and compares them to a predefined number sequence. If the sequence matches, the content of the EEPROM is copied to specified locations in the processors external RAM. Execution of the software stored within the ROM **2222, 2224, 2226** of the transceiver **2212, 2214, 2216** then continues.

[0151] Within a "config" data block in the external RAM of a processor included within each host/device transceiver **2212, 2214, 2216**, the software stored within ROM **2222, 2224, 2226** expects to find certain critical operating parameters. This data block is initialized by the software stored within ROM **2222, 2224, 2226** upon start up. If no EEPROM patch software is present; the software stored within ROM **2222, 2224, 2226** uses the values loaded at start up. If a patch EEPROM **2232, 2234, 2236** is present, the config data block can optionally be over-written as the contents of the patch EEPROM **2232, 2234, 2236** are read.

[0152] The software stored within ROM **2222, 2224, 2226** also expects to find a control table potentially containing pointers to code patches within external RAM of the applicable processor. Each pointer potentially points to a ROM code replacement function. For most entries in this table a null pointer value is expected. If a null entry is found, the software stored within ROM **2222, 2224, 2226** executes the original ROM code function for that pointer location. However, if the software within the patch EEPROM **2232, 2234, 2236** over-writes the control table value with a non-null pointer, the replacement function referenced by the pointer is executed in place of the ROM code function. Replacement functions can be other functions previously defined in ROM **2222**, **2224**, **2226**, or newly-defined functions loaded from the patch EEPROM **2232**, **2234**, **2236** to RAM at start up.

[**0153**] Consistent with the invention, the EEPROM patching procedure discussed above may be used for a variety of purposes including, for example, for default parameter substitutions, procedure substitutions, and the execution of precompiled functions. The first two of these potential uses is summarized below.

[**0154**] Parameter Substitutions

[**0155**] Those parameters assigned default ROM values which may be replaced (i.e., "substitutable parameters") are defined in a predefined file within the patch EEPROM **2232**, **2234**, **2236**. This file declares a predefined type (i.e., "Mask ROM Config t") which, when instantiated, defines the available substitutable parameters.

[**0156**] Procedure Substitutions

[**0157**] A predefined file (i.e., "MRCONT.H") contains the type definition for the Mask ROM Control "t" type referenced above. By default this structure is instantiated as a series of null function pointers. Each null pointer is a placeholder for a potential substitute procedure of the general form illustratively represented by **FIG. 24**. In order to substitute a new function for a default function, the null function pointer corresponding to the default procedure is replaced with a function pointer pointing to the new replacement procedure. Replacement procedures are located in the RAM program area (loaded from the applicable patch EEPROM **2232**, **2234**, **2236** on power up). Alternatively, replacement procedures can reference the preexisting functions in the code within ROM **2222**, **2224**, **2226**.

Operation of Host Wireless Unit

[**0158**] As may be appreciated by reference to **FIG. 3-5**, in the exemplary embodiment the architecture of the host wireless unit **112** (or, equivalently, "host transceiver **112**") is substantially similar to that of the device wireless units **114**, **116**. Accordingly, for the sake of clarity of presentation the following discussion does not repeat those aspects of the preceding discussion equally applicable to the host and device wireless units, and is instead intended to highlight the structural and operational differences there between.

[**0159**] Host Transceiver Message Format

[**0160**] As mentioned above, Table I provides information regarding each of the messages transmitted from the keyboard/mouse wireless units **114**, **116** to the host wireless unit **112**, and vice-versa. As may be appreciated by reference to Table I, the host transceiver **112** sends messages containing the following 24-bit payloads:

[**0161**] Pairing request: Most significant (MS) byte identifies message, least significant (LS) bits specify device ID. Only sent to reserved pairing ID.

[**0162**] Configuration: MS byte identifies message, middle byte specifies a configuration register or memory location, and low byte contains data to be written to the specified register or memory location.

[**0163**] Optical mouse command: MS byte identifies message, middle byte specifies optical mouse chip register, low byte specifies value to be written to the optical mouse chip.

[**0164**] GPIO read: MS byte identifies command, middle byte specifies a GPIO group. LS byte unused.

[**0165**] CPIO write: MS byte identifies command, middle byte specifies a GPIO group, LS byte contains data to be written to the GPIO pins of the specified group.

[**0166**] Shutdown message: Sent only on behalf of the host PC **102**. The destination wireless unit **114**, **116** sends an ACK upon receipt of a Shutdown message, then goes to its lowest-power state. Note that a wakeup message, which is described in the above-referenced copending patent application, will not "rouse" a wireless unit **114**, **116** from its lowest-power state.

[**0167**] Keep-Alive: Optionally used in order to detect when a wireless unit **0**.**114**, **116** moves out of range of the host wireless unit. In response to receipt of a Keep-Alive message, the wireless unit **114**, **116** sends an ACK and then may sleep for the configured keep-alive interval.

Power Management

[**0168**] In the exemplary embodiment the system **100** implements a power management scheme consistent with the "OnNow" initiative for system-wide power management defined by Microsoft Corporation. As part of this initiative, Microsoft has published "Device Class Power Management Reference Specifications" for various device classes, including the input device class applicable to keyboards, mice, joysticks, and the like (see, e.g., www.microsoft.com). The Reference Specifications for the input device class defines four power states, D0 through D3. A device operative in the D0 state is completely active and normally functioning, and consumes power at the highest level possible. In contrast, state D3 corresponds to the case in which power may have been fully removed from the device, and it considered to be completely "off". As state D2 has been characterized as being inapplicable to input devices, the only remaining state is D1. The D1 state requires that device power consumption be equal to or greater than the D2 state, but less than the D0 state. Accordingly, in the D1 state hardware such as displays and indicators (e.g., LED devices) are turned off, but state information such as num, caps, and scroll lock state are preserved. In the exemplary embodiment transitions between power states within a device are explicitly commanded by drivers within the PC host, and are not performed autonomously.

[**0169**] Consistent with one aspect of the present invention, host wireless unit **112** and keyboard/mouse wireless units **114**, **116** define a power state D1 as follows:

[**0170**] Upon receipt of a "go to D1" command via a PS/2 port, the host wireless unit **112** transmits a power down message to all connected keyboard/mouse wireless units **114**, **116**.

[**0171**] The host wireless unit **112**, after receiving all necessary ACK's, shuts off its RF unit **314** (both transmitter and receiver) and all LED devices.

[**0172**] After performing the above shut down operations, the processor of the host wireless unit **112** halts in a mode where a PS/2 interrupt or power cycling is the only way to wake it up. The wireless unit **112** should be in the lowest power consumption state possible, consistent with receiving a PS/2 message.

[**0173**] A keyboard/mouse wireless unit **114**, **116**, upon receiving a power down message, sends an ACK in response and waits for an ACK timeout period in order to ensure that the ACK is received. Following expiration of this time out period, the wireless unit **114, 116** shuts down both the transmitter and receiver of its RF unit **414**, **514**. In the case of the mouse wireless unit **116**, instructions are also provided to any optical mouse chip within its wireless mouse **106** to enter a power down state.

[**0174**] The keyboard/mouse wireless unit **114**, **116** then enters a sleep mode until a key of the wireless keyboard **104** or wireless mouse **106** is pressed, as applicable.

[**0175**] Once the keyboard/mouse wireless unit **114**, **116** wakes up in response to the occurrence of such a key press, it resumes operation, retaining the device ID of any paired devices. Such resumption of operation generally entails: (i) restoring the LED devices of the wireless keyboard/mouse **104**, **106**, and (ii) turning on the receiver of its RF unit **414**, **514**, utilizing the same rate and channel selections as were in place prior to sleep mode being entered.

[**0176**] Upon waking up, the keyboard/mouse wireless unit **114**, **116** also attempts to send a reset message to the host wireless unit **112**. Failure is handled as before; that is, the key press initiating the wakeup operation is discarded.

Collision Avoidance and Interference Handling
Collision Avoidance

[**0177**] **FIG. 14** depicts a flowchart **1400** representative of a carrier sense/clear channel assessment procedure (CS/CCA) procedure executed by the MAC layer **208** of the keyboard/mouse wireless unit **114, 116** prior to transmission of a message. As shown, in the event a message needs to be transmitted by the keyboard/mouse wireless unit **114**, **116**, the receiver of its RF unit **414**, **514** is enabled and it waits for a predefined period for PLL locking to occur. Next, the receiver of its RF unit **414**, **514** provides a CCA report indicative of the level of interference present within the channel in which it desired to transmit the message. In the exemplary embodiment a 1-bit CCA report is provided by the RF unit **414**, **514**; namely, a CCA of "1" indicates the channel is busy, and a CCA of "0" indicates the channel is clear. The details of the remainder of CS/CCA procedure is illustrated by **FIG. 14**

[**0178**] The duration of the random backoff (B) occurring within the CS/CCA procedure **FIG. 14** may be expressed as B=Bmin+N*W, where:

[**0179**] Bmin=Packet duration+T_{tx}+Trx+TMAC+T_{PLL}+ACK–duration+Ttx

[**0180**] T_{MAC}=MAC processing time (assuming 150 μs)

[**0181**] T_{PLL}=PLL switching time=150 μs

[**0182**] Ttx=transmitter latency

[**0183**] Trx=receiver latency

[**0184**] and where W=0.5*Bmin and N is a random integer (e.g., 0<=N<=S3). In addition, the "window T" referenced in **FIG. 14** corresponds to the on-air turnaround time between the transmitter and receiver of different wireless units in the case of an ACK, and is given by T=T_{PLL}+T_{MAC}+Ttx

[**0185**] The transmitter latency (Ttx) and receiver latency (Ttx) for various data rates are provided in Table V, and the durations of various types of message packets are set forth in Table VI.

TABLE V

Data rate	Ttx (μs)	Trx (μs)
112.5 kb/s	29	21
28.125 kb/s	82	67
9.375 kb/s	224	138

[**0186**]

TABLE VI

Data rate	Packet duration for keyboard (μs)	Packet duration for mouse (μs)	Duration for normal ACK (μs)	Duration for "piggy-back" ACK (μs)
112.5 kb/s	596	738	312	738
28.125 kb/s	2,383	2,952	1,245	2,952
9.375 kb/s	7,147	8,854	3,734	8,854
Spreading	6,556	8,118	3,432	8,118

[**0187**] Table VII provides a tabular listing of the value of Bmin as a function of data rate.

TABLE VII

	Bmin (ms)	
Data rate	Keyboard	Mouse
112.5 kb/s	1.287	1.429
28.125 kb/s.	4.159	4.728
9.375 kb/s	11.767	13.474
Spreading	10.367	11.929

[**0188**] In the exemplary embodiment the CCA threshold level utilized by the RF unit **414**, **514** in generating the CCA report during execution of the CS/CCA procedure illustrated by **FIG. 14** does not remain the same for all applications. Rather, even for a given application, the CCA **20** threshold level will generally depend upon the distance between the transmitting/receiving devices as well as the distance between an interferer and such devices.

[**0189**] Turning now to **FIG. 15**, a flowchart **1500** is provided of procedure for dynamically adjusting the CCA threshold level used by the RF unit **414**, **514** when generating a CCA report. In the embodiment of **FIG. 15**, the default values are: M=–60 dBm, N=2000 packets, x=60%, y=10%, and b=7%, where M, N, x, y, a, and b are configurable parameters.

[0190] Table VIII shows an exemplary mapping between CCA threshold level (TH) and RF control signals:

TABLE VIII

CCA_Vth_b2	CCA_Vth_b1	CCA_Vth_b0	CCA threshold level (TH)
0	0	0	−48 dBm
0	0	1	−54 dBm
0	1	0	−60 dBm
0	1	1	−66 dBm
1	1	0	−72 dBm
1	1	1	−78 dBm

[0191] In Table VIII, it is noted that (CCA_Vth_b2=1, CCA_Vth_b1=0 CCA_Vth_b0=0) and (CCA_Vth_b2=1, CCA_Vth_b1=0 CCA_Vth b0=1) are not used. CCA_Vth_b2, CCA_Vth_b1 and CCA_Vth_b0 are three control line bits used to set the CCA threshold level.

Interference. Handling

[0192] **FIG. 16** is a high-level flow diagram representative of a general approach to interference handling consistent with the present invention. As was discussed above, data is transmitted and received by wireless units in four different modes: a high data rate (HDR) mode; a medium data rate (MDR) mode; a low data rate (LDR) mode and a spreading mode. The HDR mode is the default mode, which can provide 150 kbps data transmission. The data rates for the MDR, LDR and spread mode are 30 kbps, 10 kbps and 13.64 kbps respectively. Spreading mode is used when there is interference from similar wireless device(s) (e.g., other host and device transceivers), and MDR is used when there is strong interference (e.g., narrow-band interference) such as from citizen band (CB) radio. In certain embodiments each wireless unit **112**, **114**, **116** is able to detect interference and switch to appropriate modes automatically. As a consequence, highly reliable wireless data transfers may be affected even in an environment with multiple other wireless users.

[0193] Normal/Spreading Mode and Spreading/Normal Mode Switching

[0194] Consistent with one aspect of the invention, spreading mode may be invoked to mitigate interference engendered by the presence of other host/device transceivers within the vicinity of a host/device transceiver pair desiring to communicate. In an exemplary embodiment the device transceiver of a host/device transceiver pair controls the switching between normal and spreading mode.

[0195] A device transceiver **114**, **116** initiates spreading mode operation by sending, to the host transceiver **112**, a packet, which has been spread in the manner described in the above-referenced copending patent application. Upon receiving a packet in spreading mode, the modem **308** at the host transceiver **308** will notify the MAC layer **208** that spreading mode has been enabled, which results in the host transceiver **112** also sending the ACK in spreading mode.

[0196] If the host transceiver **112** and device transceiver **114**, **116** are in spreading mode and the device transceiver **114**, **116** makes decision to switch to normal mode, the device transceiver **114**, **116** will send a packet in normal mode. Upon receiving this packet in normal mode, the modem **308** at the host transceiver **112** notifies the MAC layer **208** that the device transceiver **114**, **116** has switched back to normal mode. This results in the host transceiver **112** sending the ACK in normal mode.

[0197] Of course, a given host transceiver **112** will generally be in communication with more than one device transceiver **114**, **116**. Accordingly, the host transceiver **112** is disposed to **20** communicate with each device transceiver **114**, **116** in accordance with the mode that has been currently selected by such transceiver **114**, **116**.

[0198] In the exemplary embodiment the device transceivers **114**, **116** elect to switch from normal mode to spreading mode when more than a predefined number of failures occur within a predefined number of the most recent transmissions. For example, it has been found that switching to spreading mode is appropriate if more than 21 failures occur in connection with the most recent 25 attempted transmissions. Similarly, the device transceivers **114**, **116** may elect to switch from spreading mode to normal mode when less than a predefined number of failures occur within a predefined number of the most recent transmissions. For example, it has been found that a return to normal mode from spreading mode may be when less than 18 failures occur in connection with the most recent 25 transmissions.

[0199] Switching Between HDR and MDR

[0200] Turning now to **FIG. 17**, a flow chart **1700** is provided of an exemplary manner in which the host transceiver **112** transitions between operation within the HDR and MDR modes, and vice-versa. In the exemplary embodiment a transition is made from HDR to MDR mode when a received signal strength indication (RSSI) generated by the RF unit **314** indicates the presence of strong interference (e.g., narrow-band interference) such as from citizen band (CB) radio.

[0201] Within the host transceiver **112**, the RSSI generated by the RF unit **314** is checked periodically (e.g., every 2 ms). If it is determined to be necessary to switch to MDR mode, switching occurs to a particular MDR channel in accordance with the sequence 0-3-1-4-2-0 . . . . In the case of the initial switch from HDR to MDR mode, the host transceiver **112** first attempts to operate in a predefined MDR channel (e.g., channel **4**). If in fact "L" is the channel through which the host/device transceivers are communicating immediately prior to transitioning back to operation in HDR mode (i.e., in the event the RSSI again becomes sufficiently low to warrant HDR mode operation), then the host transceiver **112** will switch to channel "L" the next time a transition to MDR mode is required.

[0202] When in the HDR mode and the host transceiver has determined RSSI to be high for K seconds, the mode is switched to the MDR mode. While RSSI is high in the MDR mode, the host transceiver listens for N seconds. If a message is received, the host transceiver stays in the channel in which the message was received. The transceiver remains on the channel provided no interval of greater than M seconds elapses without receiving a message. If after M seconds no message is received and RSSI remains high the communication channel is switched to the next channel and the encryption is reset. Then the host transceiver listens again for N seconds. After N seconds the next channel is selected. After each channel has been selected and no message has been received the transceiver is switched back to the HDR mode and the encryption is reset. In an exemplary embodiment the following values are utilized for the parameters identified in **FIG. 17**: N=100 ms, M=5 second and K=100 ms.

[**0203**] Referring to **FIG. 18**, a flow chart **1800** is provided of an exemplary manner in which a device transceiver **114**, **116** transitions between operation within the HDR and MDR modes, and vice-versa. As in the case of the host transceiver **112**, a device transceiver **114**, **116** transitions from the HDR to MDR mode when an RSSI generated by the applicable RF unit **414**, **514** indicates the presence of strong interference (e.g., narrow-band interference).

[**0204**] As shown in **FIG. 18**, when the device transceiver **114**, **116** is in receiving mode (i.e., in order to receive the ACK), RSSI from the RF unit **414**, **514** is checked. If it is determined to be necessary to switch to MDR mode, switching occurs to a particular MDR channel in accordance with the sequence -3-1-4-2-0 . . . . In the case of the initial switch from HDR to MDR mode, the device transceiver **114**, **116** first attempts to operate in a predefined MDR channel (e.g., channel **4**). If in fact "L" is the channel through which the host/device transceivers are communicating immediately prior to transitioning back to operation in HDR mode (i.e., in the event the RSSI again becomes sufficiently low to warrant HDR mode operation), then the device transceiver **114**, **116** will switch to channel "L" the next time a transition to MDR mode is required.

[**0205**] In an exemplary embodiment the following values are utilized for the parameters identified in **FIG. 18**: Timer**1**=50 ms, Timer**2**=1 seconds and T=100 ms.

Power-Saving Operation During USB Suspend State

[**0206**] As was indicated above, in certain embodiments the host transceiver **112** may be incorporated within a dongle or the like and connected to the host PC **102** through a Universal Serial Bus (USB). Those skilled in the art are aware that the USB is a personal computer (PC) interconnect capable of supporting simultaneous attachment of multiple devices. In the exemplary embodiment the host transceiver **112** includes an integrated USB function controller **10** and a full speed (12 Mb/s) transceiver.

[**0207**] USB devices may be self-powered or receive energy via the USB cable through which they communicate with a hosting entity. USB supports a variety of power modes: On, Suspend, and Off. When placed in Suspend mode, USB devices retain the ability to wakeup the hosting system.

[**0208**] A number of requirements are imposed upon devices, which are placed on a USB. See, e.g., "An Overview of the Universal Serial Bus (USB), Part **1**", SSS Online (December 2000). For example, a device placed on the bus is permitted to draw up to 500 mA; however, many hosting entities will not permit a device to draw more than 100 mA from the bus. Consistent with the USB protocol, the host transceiver **112** informs the host PC **102** as to the amount of current required for its operation. However, when the host transceiver **112** enters the Suspend mode in accordance with the USB protocol, it cannot draw any more than 500 uA from the bus (assuming the host transceiver is bus-powered rather than battery-powered). In this regard the USB protocol requires the host transceiver **112** to enter the Suspend state if its bus has been inactive for 3 ms. The host PC **102** can initiate a resume command to the host transceiver **112** when it is in Suspend mode. Similarly, the host transceiver **112** can also issue a remote wakeup to the host PC when it is inactive in order to render it active.

[**0209**] In view of the limitations on the amount of current which can be drawn by the host transceiver **112** from its USB during operation in Suspend mode, it will generally not be possible for the host transceiver **112** to remain "awake" (i.e., fully operational) at all times when operative in this mode. Accordingly, in accordance with one aspect of the invention the host transceiver **112** only periodically becomes fully operational and capable of receiving messages from device transceivers **114**, **116** when functioning in Suspend mode. As is discussed below, the messaging protocols of any device transceivers **114**, **116** in communication with a host transceiver **112** are also modified upon entry of the host transceiver **112** into Suspend mode.

[**0210**] Turning now to **FIG. 19**, a timing diagram **1900** is provided which is representative of the transition of the host transceiver **112** into and out of "awake" and "sleep state" operation during its operation in Suspend mode consistent with the USB protocol. As shown, the host transceiver operates in an awake state for a period of W ms once every B ms, and is otherwise in a sleep state. Each awake period will generally be of the same duration and of sufficient length to permit capturing of the header of a message packet transmitted by a device transceiver. **114**, **116**. In order to facilitate understanding of this aspect of the invention, exemplary computations of appropriate values of the parameters W and B are given below for the case of transmissions by the mouse transceiver **116** during both normal and spreading mode operation.

[**0211**] During normal mode operation, the worst-case time required to capture the header of a packet transmitted by the mouse transceiver **116** (i.e., the awake period W) may be expressed as:

$$\begin{aligned} W &= Tosc + T_{PLL} + \text{Packet duration} + Ttx + T_{PLL} + \\ &\quad ACK \text{ time-out duration} + T_{PLL} + \\ &\quad \text{acquisition sequence/header duration} \\ &= (500 + 200 + 573 + 11 + 200 + 253 + 200 + 253)\ \mu\text{s}, \\ &\quad \text{for } HDR \text{ mode} \\ &= 2.190 \text{ ms, for } HDR \text{ mode} \end{aligned}$$

[**0212**] where,

[**0213**] Tosc=time for oscillator warm up=500 μs

[**0214**] $T_{PPL=time}$ for PLL settling=200 μs

[**0215**] Ttx=transmission latency=11 μs

[**0216**] In an exemplary implementation of the host transceiver **112**, its power consumption during an awake time of 2.190 ms is estimated to be =44 ms×mA. It follows that the interval (B) between awake periods should be <=(44 mA ms)/(2.5 mA), or 17.6 ms. That is, when operative in

Suspend mode the host transceiver enters an awake state every 17.6 ms (for HDR mode), and is otherwise in sleep state.

[0217] During spreading mode operation, the worst-case time required to capture the header of a packet transmitted by the mouse transceiver **11.6** (i.e., the awake period W) may be expressed as:

$$\begin{aligned} W &= Tosc + T_{PLL} + \text{Packet duration} + Ttx + T_{PLL} + \\ &\quad ACK\ \text{time-out duration} + T_{PLL} + \\ &\quad \text{acquisition sequence/header duration} \\ &= (500 + 200 + 573*11 + 11 + 200 + 253*11 + 200 + 253*11) \\ &\quad \mu\text{s, for } HDR \text{ mode} \\ &= 13.0 \text{ ms, for } HDR \text{ mode} \end{aligned}$$

[0218] where,

[0219] Tosc=time for oscillator warm up 500 μs.

[0220] T_{PLL}=time for PLL settling=200 μs.

[0221] Ttx=transmitter latency=11 μs.

[0222] In an exemplary implementation of the host transceiver **112**, its power consumption during an awake time of 13.0 ms during spreading mode is estimated to be 314.25 ms×mA. It follows that the interval (B) between awake periods should be <=(314.25 mA ms)/(2.5 mA), 125.7 ms. That is, when operative in Suspend mode the host transceiver enters an awake state every 125.7 ms (for HDR mode), and is otherwise in sleep state.

[0223] Referring now to **FIG. 20**, there is shown a state transition diagram **2000** representative of the operation of the transceiver **112** when in Suspend mode. As is indicated by **FIG. 20**, the transceiver **112** transitions from sleep state to awake state every awake period of B ms, and remains in awake state for W ms. If validation of the header of a message from the mouse transceiver **116** occurs during the W ms duration of an awake state, the host transceiver remains in the awake state. If such a header validation occurs and no packets are received for N ms, the host transceiver **112** returns to sleep state.

[0224] Turning now to **FIG. 21**, a state transition diagram **2100** depicts the corresponding modifications to the messaging protocol of the mouse transceiver **116** upon entry of its partner host transceiver **112** into Suspend mode. As shown, in this context the mouse transceiver **116** is disposed to re-transmit a packet if an ACK is not received in response to the initial transmission of the packet. If a predefined number of such re-transmissions also fail, the mouse transceiver **116** sends link-reset packets. If these link-reset packets also fail to result in a resetting of the applicable communication link, then the moue transceiver **116** transmits link-reset packets for E ms if no packets are queued for transmission; otherwise, the next queued packet is transmitted and operation continues as described above.

[0225] In the embodiment of **FIGS. 19-21**, the parameters E, B, W, and N are configurable. An **25** exemplary set of default values of these parameters are B=140 ms, W=14 ms, E=140 ms, N=140 ms.

[0226] The foregoing description, for purposes of explanation, used specific nomenclature to provide a thorough understanding of the invention. However, it will be apparent to one skilled in the art that the specific details are not required in order to practice the invention. In other instances, well-known circuits and devices are shown in block diagram form in order to avoid unnecessary distraction from the underlying invention. Thus, the foregoing descriptions of specific embodiments of the present invention are presented for purposes of illustration and description. They are not intended to be exhaustive or to limit the invention to the precise forms disclosed, obviously many modifications and variations are possible in view of the above teachings. The embodiments were chosen and described in order to best explain the principles of the invention and its practical applications, to thereby enable others skilled in the art to best utilize the invention and various embodiments with various modifications as are suited to the particular use contemplated.

[0227] While the invention has been particularly shown and described with reference to preferred embodiments thereof, it will be understood by those skilled in the art that various changes in form and details may be made without departing from the spirit and scope of the invention.

What is claimed is:

1. A method of communication between a media access control (MAC) and a radio unit within a transceiver, comprising:

a) writing a device ID of said receiving device to a radio unit;

b) enabling read mode, and receiving a message;

c) processing said message and preparing an acknowledgement (ACK) message;

d) disabling read mode;

e) setting up registers in said radio unit and enabling send mode; and

f) sending said ACK message and disabling send mode upon completion of sending said ACK message.

2. The method of claim 1, wherein processing said message includes a cyclical redundancy check (CRC) whereby said ACK message is blocked if the CRC finds said message to be bad.

3. A method for changing operating states of a wireless communication system under a control of a media access control (MAC) unit, comprising:

a) operating in a high data rate (HDR) mode when a received signal strength indicator (RSSI) is high and changing to a medium data rate (MDR);

b) selecting a next MDR channel when an acknowledgement (ACK) message timer expires;

c) changing to said HDR mode from said MDR mode when all available said MDR channels have been tried and said ACK timer expires for each said available MDR channels; and

d) changing to said HDR mode when RSSI is low and operating in said HDR mode when RSSI is low.

4. The method of claim 3, wherein said RSSI is monitored by a radio frequency unit coupled to said MAC and provides an indication of the strength of other signals, or noise, operating on said MDR channel.

5. The method of claim 3, wherein said next MDR channel is selected from a plurality of channels in which no two adjacent channels are selected in an immediate sequence to reduce the possibility that unwanted signals on a first selected channel being present on a second channel.

6. A method for collision avoidance and information handling, comprising;

a) preparing to send a message from a peripheral RF transceiver;

b) enabling an RF receiver and waiting for locking of a phase lock loop;

c) performing a clear channel assessment CCA by the RF receiver;

d) performing a random backoff if a channel is busy and then switch to a transmit mode;

e) awaiting a window of time T, then check the CCA report from said RF receiver, if channel is not busy, then switch to transmit mode, otherwise if channel is busy, perform a random backoff, then switch to transmit mode;

f) transmitting said message and after switching to said RF receiver to wait for an acknowledgement (ACK) that the message transmitted was received and ending if an ACK is received;

g) returning to step c) if there is no ACK and a number of transmissions has not exceeded a maximum;

h) exiting process if the number of transmissions has exceeded the maximum and waiting for a new message.

7. The method of claim 6, wherein said CCA is a measurement of a level of interference within said channel.

8. The method of claim 6, wherein said random backoff is a function a size of said message, a transmitter and a receiver latency, a time to process for preparing to send said message and switching time of said phase lock loop.

9. The method of claim 6, wherein said window of time T is a function of a switching time of said phase lock loop, a time to process for preparing to send said message and a transmission latency.

10. A method for dynamically adjusting a clear channel assessment (CCA), comprising:

a) setting a CCA threshold to a default value;

b) measuring performance and backoff rates for a plurality of sent radio frequency (RF) messages;

c) increasing said CCA threshold to threshold=threshold plus a specified decibel level if the backoff rate is greater than a first backoff amount and said performance is less than a first performance amount, and returning to step b) to measure performance and backoff rates; and

d) decreasing said CCA threshold to threshold=threshold minus a specified decibel level if the backoff rate is less than a second backoff amount and said performance is greater than a second performance amount, and returning to step b) to measure performance and backoff rates.

11. The method of claim 10, wherein said backoff is a time delay before resending an RF message thereby breaking deadlocks caused by simultaneous RF transmissions.

12. The method of claim 10, wherein said CCA is a measurement of a level of interference within a communication channel.

13. A method for interference handling, comprising:

a) receiving a received signal strength indication (RSSI) at an radio frequency (RF) transceiver;

b) applying a high data rate (HDR) or a medium data rate (MDR) when said RSSI is high, which signifies a relatively high degree of RF interference; and

c) checking conditions to go between a spreading mode and an MDR mode when said RSSI is low, which signifies a relatively low degree of RF interference.

14. The method of claim 13, wherein said HDR is a default data rate mode.

15. The method of claim 13, wherein said MDR is used when there is a strong interference such as might be caused by a citizen band radio.

16. The method of claim 13, wherein said spreading mode is used when there is interference from devices similar to said RF transceiver.

17. A method for switching between a high data rate (HDR) and a medium data rate (MDR) at an RF transceiver, comprising:

a) continuing use of a HDR when a received signal strength indicator (RSSI) is low;

b) switching to a MDR when the RSSI is high and resetting a data encryption;

c) listening for a first period of time on a first channel of a plurality of communication channels after switching to the MDR mode;

d) continuing to communicate in said first channel when said RF message is received, listening for a second period of time, and receiving additional RF messages;

e) switching to a second channel of said plurality of communication channels and resetting said encryption after listening and receiving no RF messages on said first channel, then returning to step c);

f) switching the HDR mode after switching through all available channels of said plurality of channels when in the MDR mode until said all available channels have been used and no RF messages have been received; and

g) switching to the HDR mode and resetting the encryption when the RSSI is low.

18. The method of claim 17, wherein switching to the HDR model further comprises:

a) resetting encryption and listening for a third period of time; and

b) switching to the MDR mode and changing encryption when RSSI is high and no RF message is received during said third period of time.

19. The method of claim 18, wherein said third period of time is for a plurality of seconds.

20. The method of claim 17, wherein said first and second periods of time is for a plurality of milliseconds.

21. The method of claim 17, wherein said plurality of channel are selected in a sequence where no two channels having adjacent frequencies are selected as a next channel from said plurality of channels.

22. A method for performing in a medium data rate (MDR) mode, comprising;

a) transmitting a first RF message in a MDR mode over a first communication channel and listening for an first acknowledgement (ACK);

b) remaining in said first communication channel if said first ACK is received, transmitting a second RF message and waiting for a second ACK;

c) remaining in said first communication channel if said second ACK is received;

d) retransmitting said second RF message as a first retransmission of said second RF message and waiting for a third ACK and remaining in said first communication channel if said third ACK is received; and

e) retransmitting said second RF message as a second retransmission of the second RF message if a first timer has not expired and if said third ACK is not received, otherwise switch a second communication channel and reset encryption.

23. The method of claim 22, wherein transmitting said first RF message further comprises:

a) switching to said second communication channel and resetting encryption if said first ACK of the first RF message is not received;

b) retransmitting said first RF message as a first retransmission of said first RF message and remaining in said second communication channel if said ACK to said first retransmission of said RF message is received;

c) switching to a third communication channel, resetting encryption, retransmitting said first RF message as a second retransmission if a second timer has not expired; and

d) switching to a high data rate (HDR), resetting encryption mode, retransmitting said first RF message as a third retransmission of said first RF message and listening for said ACK for the third retransmission and returning to said MDR mode if no said ACK received, a third timer has expired and a received signal strength indicator is high.

24. The method of claim 23, wherein said second timer is in the order of seconds and said third timer is in the order of milliseconds.

25. The method of claim 22, wherein said first timer is in the order of milliseconds.

26. A method for a host transceiver in suspend mode, comprising:

a) waiting for a first period of time and entering an awake state;

b) listening for RF messages during a second period of time, detecting no valid header data, entering a sleep state, and returning to step a);

c) validating a header of a message, listening for a third period of time, receiving no data packet, entering a sleep state and returning to step a); and

d) validating said header of a message, listening for a third period of time, receiving a packet of data, remaining in said awake state and returning to step b).

27. The method of claim 26, wherein said first period of time is an amount of time between said awake states.

28. The method of claim 25, wherein said second period of time is an amount of time in which the host is awake.

29. The method of claim 25, wherein said third period of time necessary to receive said data packet and respond with an acknowledgement.

30. A method for modifying messaging protocol of a mouse transceiver upon entry of a host transceiver into a suspend mode, comprising:

a) transmitting a first message from a mouse to a host transceiver and if an acknowledgement ACK is received by said mouse continue transmitting additional messages;

b) re-transmitting said first message if ACK is received, then continue transmitting additional messages;

c) re-transmitting said first message if ACK not received and if a predefined number of retransmissions has not been exceeded;

d) sending a link reset from said mouse to said host transceiver if a predefined number of retransmissions has not been exceeded;

e) receiving ACK from said host transceiver for said link reset and returning to transmitting messages from said mouse to said host;

f) sending said link reset from said mouse to said host transceiver if no ACK for link reset received from said host transceiver and if said predetermined number of said link reset not exceeded; then g) transmitting a second message if said second message packet is in a queue; and

h) sending said link reset for a period of time if no said message packet is in the queue.

31. The method of claim 30, wherein said period of time is a plurality of milliseconds that is reconfigurable.

32. A computing system using radio frequency (RF) signals to communicate between a plurality of computing units, comprising:

a) a plurality of transceivers located in a plurality of computing units and communicating between said plurality of computing units with RF signals;

b) each transceiver of said plurality of transceivers contain a software ROM that controls operations of said each transceiver; and

c) a software patch EEPROM added to said each transceiver to allow modifications and additions to commands contained within said software ROM.

33. The computing system of claim 32, wherein said plurality of computing units comprise a host computer, a keyboard and a mouse.

34. The computing system of claim 32, wherein said each transceiver controls communications and is personalized to the characteristics of each computing unit of said plurality of computing units with said ROM and said EEPROM.

35. A method for using a patch EEPROM for controlling operations of a radio frequency (RF) transceiver, comprising:

a) initializing a transceiver in a computing unit;

b) copying an EEPROM into RAM if a patch EEPROM exists then resuming initialization from a ROM; and

c) continuing operation using said ROM if a patch EEPROM does not exist.

36. The method of claim 35, wherein said ROM provides commands for operating said transceiver.

37. The method of claim 35, wherein said EEPROM provides modified and additional commands for operating said transceiver.

38. A method for using null function pointers to substitute a new function into an operation of a radio frequency (RF) transceiver, comprising:

a) calling a substitute function if a function pointer is not equal to null and continuing operation of a RF transceiver; and

b) running an original function if said function pointer is null and continuing operation of said RF transceiver.

39. The method of claim 38, wherein said substitute function replaces a default function when a default pointer is replaced with said function pointer.

40. The method of claim 38, wherein said substitute function resides in memory and is loaded into said memory upon power-on of said transceiver.

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