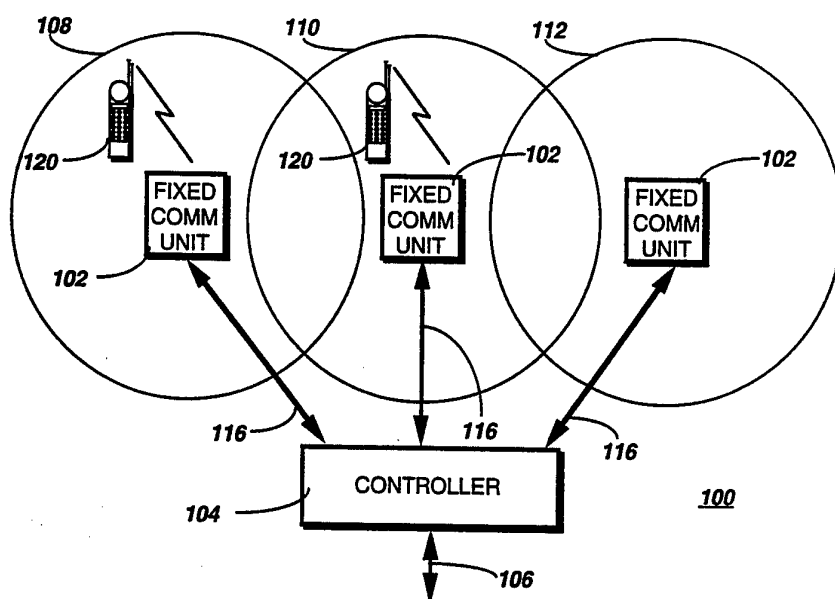




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(54) Title: METHOD AND APPARATUS FOR PERFORMING A HAND-OFF IN A WIRELESS COMMUNICATION SYSTEM



(57) Abstract

A method and apparatus for performing a hand-off in a wireless communication system (100) comprise a plurality of fixed communication units (102) and a controller (104) coupled to the plurality of fixed communication units (102), and further comprise a portable communication unit (120). The method comprises the steps of: receiving (504) from the controller a common master synchronization signal, and receiving (524) from the controller a request to monitor receivable transmissions from the portable communication unit (120) on the original channel. The method further comprises performing (526) synchronous monitoring of the receivable transmissions from the portable communication unit (120) on the original channel, the synchronous monitoring being synchronized by the common master synchronization signal.

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METHOD AND APPARATUS FOR PERFORMING A HAND-OFF IN A
WIRELESS COMMUNICATION SYSTEM

Field of the Invention

5 This invention relates in general to wireless
communication systems, and more specifically to wireless
communication systems having the capability of handing-off
a portable communication unit from a first fixed
10 communication unit to a second fixed communication unit.

Background of the Invention

Two-way radio communication systems that support hand-
15 off are well known in the art. An example of such a system
is a cellular mobile telephone system. Other systems such
as those based on the Digital European Cordless
Telecommunications (DECT) standard have been proposed and
are under development by equipment vendors around the
20 world.

Conventional analog radio communication systems that
have a plurality of radio coverage areas defined by a
limited transmission distance of a fixed communication unit
in each of the radio coverage areas use a controller to
25 support hand-off. Whenever a need for handing-off a first
portable communication unit is determined by a first fixed
communication unit handling a call with the first portable
communication unit, the controller commands other fixed
communication units near the first fixed communication unit
30 to measure the received signal strength of the first
portable communication unit on a transmission channel on
which the first portable communication unit is
transmitting. To avoid a possibility of erroneously
measuring a signal transmitted from a second portable
35 communication unit, the identity of the portable
communication unit transmitting the received signal also
must be determined.

Digital communication systems based on second generation cordless telephony (CT2) technology are becoming popular. A problem exists in executing a hand-off in the conventional CT2 system, because only a fixed communication unit that has established a link with a portable communication unit can identify the portable communication unit. Other fixed communication units can measure the strength of a signal present on a channel that the portable communication unit is known to be using, but cannot confirm that the signal is coming from the "correct" portable communication unit. Worse yet, because the CT2 system is a time-division-duplex system, it is equally likely that a monitored signal may be coming from another fixed communication unit.

The cause of the identification problem is that in the conventional CT2 system there is no frame synchronization information transmitted while transmitting user data, e.g., voice communications. As a consequence, there is no way for a monitoring fixed communication unit to synchronize with and identify the source of a monitored signal. A fixed communication unit that originally establishes a link with a portable communication unit does not have a synchronization problem, because by maintaining bit synchronization with the fixed-bit-rate signals of CT2, the fixed communication unit also maintains frame synchronization obtained during link establishment.

Even if the source of the monitored signal could be positively identified, a seamless hand-off would not be possible in the conventional CT2 system. This is because the conventional CT2 system provides no way of establishing a new wireless link for accepting the hand-off without noticeably interrupting the transmission of user communications.

Thus, what is needed is a way of performing a hand-off in a CT2 system that allows confirmation of the source of a signal while monitoring the signal to select the best fixed communication unit for receiving the hand-off. Also needed is a way of doing a seamless hand-off. Whenever a seamless

hand-off is not possible, then at least a way of doing a hand-off that reduces interruption of user communications to a negligibly brief duration is needed.

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Summary of the Invention

One aspect of the present invention comprises a method in a plurality of fixed communication units for performing a hand-off from an original channel in a wireless communication system comprising a portable communication unit and a controller coupled to the plurality of fixed communication units, the method comprising the steps of:

- (a) receiving from the controller a common master synchronization signal;
- 15 (b) receiving from the controller a request to monitor receivable transmissions from the portable communication unit on the original channel; and
- (c) performing in response to step (b) synchronous monitoring of the receivable transmissions from the portable communication unit on the original channel, the synchronous monitoring being synchronized by the common master synchronization signal.

Another aspect of the present invention comprises a method in one of a plurality of fixed communication units for obtaining a hand-off from an original channel in a wireless communication system comprising a portable communication unit and a controller coupled to the plurality of fixed communication units, the method comprising the steps of:

- (a) receiving a common master synchronization signal transmitted from the controller; and
- (b) establishing a wireless link with the portable communication unit on the original channel, the link being
- 35 synchronized with the master synchronization signal.

Another aspect of the present invention comprises a method in one of a plurality of fixed communication units

for receiving a hand-off from an original channel in a wireless communication system comprising a portable communication unit and a controller coupled to the plurality of fixed communication units, the method comprising the steps of:

- (a) receiving from the controller a common master synchronization signal;
- (b) receiving from the controller a request to monitor receivable transmissions from the portable communication unit on the original channel; and
- (c) performing in response to step (b) synchronous monitoring of the receivable transmissions from the portable communication unit on the original channel, the synchronous monitoring being synchronized by the common master synchronization signal.

Another aspect of the present invention comprises an apparatus in a fixed communication unit for performing a hand-off in a wireless communication system comprising a portable communication unit and a controller coupled to a plurality of fixed communication units, the apparatus comprising:

- a synchronization element for synchronizing with a common master synchronization signal transmitted from the controller; and

- a wireless link establishment element coupled to the synchronization element for establishing a wireless link with the portable communication unit, the link being synchronized with the master synchronization signal; and

- a synchronous monitoring element coupled to the synchronization element for synchronously monitoring receivable transmissions from the portable communication unit.

Another aspect of the present invention comprises a method for performing a hand-off from an original channel in a wireless communication system comprising a portable communication unit and a controller coupled to a plurality

of fixed communication units, the method comprising the steps of:

(a) sending a common master synchronization signal from the controller to the plurality of fixed communication units;

(b) receiving a hand-off request sent from a first one of the plurality of fixed communication units;

(c) sending in response to step (b) from the controller to the plurality of fixed communication units a request to synchronously monitor receivable transmissions from the portable communication unit on the original channel, the synchronous monitoring being synchronized by the common master synchronization signal sent in step (a);

(d) receiving in response to step (c) signal strength measurements sent from ones of the plurality of fixed communication units; and

(e) handing-off a call from the first one of the plurality of fixed communication units to a second one of the plurality of fixed communication units having sent the highest signal strength measurement in step (d).

Another aspect of the present invention comprises an apparatus in a controller for performing a hand-off in a wireless communication system comprising a portable communication unit and the controller coupled to a plurality of fixed communication units, the apparatus comprising:

a synchronization element for generating a common master synchronization signal for the plurality of fixed communication units;

a controller interface element coupled to the synchronization element for interfacing with ones of the plurality of fixed communication units;

a telephone interface element for interfacing the controller to a telephone system;

a switch element for handing-off a call from a first one of the plurality of fixed communication units to

a second one of the plurality of fixed communication units;
and

a channel optimization element for optimizing the
selection of a channel for the hand-off.

5

Brief Description of the Drawings

FIG. 1 is a block diagram of a wireless communication
system in accordance with the preferred embodiment of the
present invention.

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FIG. 2 is a block diagram of a fixed communication unit
in accordance with the preferred embodiment of the present
invention.

FIG. 3 is a block diagram of a synchronizer in
accordance with the preferred embodiment of the present
invention.

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FIG. 4 is a block diagram of a controller in accordance
with the preferred embodiment of the present invention.

FIGs. 5, 6, and 7 comprise a flow chart of a method of
performing a hand-off in accordance with the preferred
embodiment of the present invention.

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FIG. 8 is a flow chart of an alternate embodiment of
the portion of the flow chart depicted in FIG. 6 in
accordance with the present invention.

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Description of the Preferred Embodiment

With reference to FIG. 1, a block diagram of a wireless
communication system 100 in accordance with the preferred
embodiment of the present invention comprises a plurality
of fixed communication units 102 coupled to a controller
104 by digital connections 116 for transporting user
communications. The fixed communication units 102 provide
wireless communication coverage within limited coverage
areas 108, 110, 112 for portable communication units 120.
The controller 104 is coupled to an external telephone
system (not shown), e.g., a private branch exchange (PBX)
or to the Public Switched Telephone Network (PSTN), by

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telephone interconnects 106 for transporting telephone calls between the portable communication units 120 and the external telephone system. The controller 104 and the fixed communication units 102 further use the digital connections 116 for communicating control and synchronization information to one another.

With reference to FIG. 2 a block diagram of the fixed communication unit 102 in accordance with the preferred embodiment of the present invention comprises radio frequency (RF) transceivers 202 coupled to a microcomputer 204 by a bus 206 for controlling the transceivers 202. The RF transceivers 202 comprise a received signal strength indication (RSSI) circuit 216 for indicating the signal strength of a received signal to the microcomputer 204. The fixed communication unit further comprises time division duplex (TDD) and adaptive differential pulse code modulation to pulse code modulation (ADPCM-PCM) transcoder circuits 208 coupled between the RF transceivers 202 and digital network interface circuits (DNICs) 212. The TDD and ADPCM-PCM transcoder circuits 208 are for converting between the ADPCM TDD signaling of the RF transceivers 202 and space-division-duplex PCM interfaces of the DNICs 212. The TDD and ADPCM-PCM transcoder circuits 208 are also coupled to the microcomputer 204 for controlling the TDD and ADPCM-PCM transcoder circuits 208 and to a synchronizer 210 for synchronizing the TDD and ADPCM-PCM transcoder circuits 208. The synchronizer 210 is coupled to the DNICs 212 for receiving synchronization information.

With reference to FIG. 3 a block diagram of the synchronizer 210 in accordance with the preferred embodiment of the present invention comprises a housekeeping bit detector 302 having a frame sync input 304, a received data input 306, and a received clock input 308. The housekeeping bit detector 302 is a shift register that stores and shifts received data from the DNIC 212 (FIG. 2) coupled to the received data input 306 at a received clock rate from a DNIC received clock port coupled to the received clock input 308. When a frame sync pulse

from the DNIC appears at the received data input 306, a bit position corresponding to a housekeeping bit (sent as an alternating 1-0 bit pattern having a repetition rate of five-hundred Hz) is enabled and latched by the housekeeping
5 bit detector 302 and thus appears at a housekeeping bit detector output 310 as a five-hundred Hz square wave.

The five-hundred Hz square wave signal from the housekeeping bit detector output 310 is coupled to an adjustable delay circuit 312 for compensating for
10 differential signal path delay between the controller 104 (FIG. 1) and the fixed communication unit 102. After delay compensation in the adjustable delay circuit 312 the five-hundred Hz square wave signal is coupled to a phase comparator 318 for comparison with a signal comprising an
15 output frequency from an output 324 of a voltage controlled oscillator (VCO) 316. An output signal of the phase comparator 318 is coupled to a low pass filter 322 to produce an error voltage coupled to an input control line 320 of the VCO 316 for controlling frequency and phase of
20 the signal from the VCO output 324. One of ordinary skill in the art will recognize that the phase comparator 318, the low pass filter 322, and the VCO 316 are arranged and connected to comprise a phase-locked loop. Operation of the phase-locked loop is such that the signal from the VCO
25 output 324 is synchronized and phase-locked with the five-hundred Hz square wave signal from the adjustable delay circuit 312.

By transmitting the same housekeeping bit stream from the controller 104 (FIG. 1) to the plurality of fixed
30 communication units 102 (FIG. 1) in accordance with the present invention as is described herein below, the plurality of fixed communication units 102 are synchronized with one another. Furthermore, because in the CT2 system the fixed communication unit 102 provides master
35 synchronization for the portable communication unit 120 (FIG. 1) during link establishment, the portable communication unit 120 advantageously is synchronized with the plurality of fixed communication units 102 that are

synchronized with one another. Thus, the plurality of fixed communication units 102 are able to synchronously monitor the transmissions of the portable communication unit 120 for identification and other purposes. This contrasts with the conventional CT2 system, in which the portable communication unit 120 is synchronized with only a single one of a plurality of unsynchronized fixed communication units 102 and cannot be synchronously monitored by the plurality of fixed communication units 102.

With reference to FIG. 4, a block diagram of the controller 104 in accordance with the preferred embodiment of the present invention comprises a controller microcomputer 402 comprising a channel database 404 for storing information comprising channel usage and physical location of each of the plurality of fixed communication units 102 (FIG. 1). The controller microcomputer 402 further comprises a channel selector 406 comprising a co-channel avoidance element 408, and adjacent-channel avoidance element 410, and an intermodulation-channel avoidance element 412. The channel selector functions to select channels for hand-off such that interference among the channels of adjacent fixed communication units 102 is minimized.

Interference is minimized by avoiding operation on the same channel or an adjacent channel (same channel ± 1) that a physically adjacent fixed communication unit 102 is using. In addition, to minimize interference from intermodulation products, if channel N1 and channel N2 are operating in adjacent fixed communication units, then channel $((2 \times N1) - N2)$ and channel $((2 \times N2) - N1)$ should be avoided. For example, if channels 3 and 5 are in use in two adjacent fixed communication units, then channels 1 and 7 should be avoided in the two adjacent fixed communication units and in any other fixed communication units near both of the two adjacent fixed communication units.

The controller microcomputer 402 is coupled to a digital switch 418 by a bus 414 for controlling the digital

switch 418. Digital telephone switches like the digital switch 418 are well-known in the art, an example being the Meridian One switch manufactured by Northern Telecom Electronics Limited of Nepean, Ontario, Canada. Also
5 coupled to the bus 414 for control are digital network interface circuits (DNICs) 416, a digital switch 418, CODECs 422, and telephone interfaces 424. The DNIC 416 is well-known in the art, an example being the MT8972B DNIC manufactured by Mitel Corporation of Kanata, Ontario,
10 Canada.

The telephone interfaces 424 are coupled to the telephone interconnects 106 for performing well-known functions such as incoming call detection, impedance matching, two-to-four wire conversion, and line
15 supervision. Coupled to the telephone interfaces are the analog interfaces of CODECs 422 for converting between an analog telephone format and a digital format used between the controller 104 and the fixed communication units 102 (FIG. 1). Coupled between digital interfaces of the CODECs
20 422 and the DNICs 416 by PCM highways 420 is the digital switch 418 for connecting each of the CODECs 422 with up to two of the DNICs 416 simultaneously.

A synchronization generator 426 for generating a five-hundred Hz square wave is coupled to a housekeeping bit
25 input 428 of each of the DNICs 416 for providing a common master synchronization for all the fixed communication units 102 (FIG. 1) controlled by the controller 104. The synchronization generator 426 is itself synchronized with a master clock that also synchronizes all the DNICs, so that
30 transitions of the five-hundred Hz square wave are locked to a frame rate of the DNICs. One of ordinary skill in the art will recognize that there can be other embodiments as well for synchronizing the fixed communication units 102 with one another in accordance with the present invention.

35 With reference to FIG. 5, a flow chart of a method of performing a hand-off in accordance with the preferred embodiment of the present invention begins with applying 502 power to apparatus in the wireless communication system

100 (FIG. 1). In response, all fixed communication units
102 (FIG. 1) synchronize 504 with the five-hundred Hz
square wave master sync signal generated by the
synchronization generator 426 (FIG. 4) and sent by the
5 housekeeping bit of the DNICs 416 (FIG. 4) as described
herein above.

In response to a call, a first fixed communication unit
102 (FIG. 1) establishes 506 a wireless link with a
portable communication unit 120 (FIG. 1) on a channel
10 herein defined as the "original channel." Because all the
fixed communication units are synchronized with the five-
hundred Hz master sync signal from the controller 104 (FIG.
4), the radio transmissions of the portable communication
unit are also synchronized with the five-hundred Hz master
15 sync signal from the controller 104. After linking with
the portable communication unit 120, the fixed
communication unit 102 reports a number identifying the
original channel to the controller microcomputer 402 (FIG.
4). The controller microcomputer 402 then stores 508 the
20 number identifying the original channel in the channel
database 404 (FIG. 4).

The microcomputer 204 of the first fixed communication
unit 102 (FIG. 2) periodically monitors 510 a received
signal strength indication (RSSI) of signals transmitted by
25 the portable communication unit 120 (FIG. 1). The
microcomputer 204 does this by reading an output signal
from the RSSI circuit 216 (FIG. 2). If in step 512 the
microcomputer 204 finds the RSSI above a pre-determined
minimum value, the microcomputer 204 continues to monitor
30 510 the RSSI. If, on the other hand, in step 512 the
microcomputer 204 finds the RSSI below a pre-determined
minimum value, the microcomputer 204 sends 516 a message
over one of the digital connections 116 (FIG. 1) to the
controller microcomputer 402 (FIG. 4), requesting the
35 controller microcomputer 402 to hand-off the portable
communication unit 120 to a fixed communication unit 102
better able to receive the portable communication unit 120.
In response, the controller microcomputer 402 checks 520

the channel database 404 (FIG. 4) to determine whether any transceivers 202 (FIG. 2) are available in any of the fixed communication units 102 near the first fixed communication unit 102 to accept the call. If no transceivers 202 are
5 available, a hand-off is not possible and the controller microcomputer 402 sends 522 a message back to the microcomputer 204 of the first fixed communication unit 102. The message instructs the microcomputer 204 to send a message to the portable communication unit 120 for
10 generating an audible indication to inform a user that the user is going out of transmission range and should stop moving.

If, on the other hand, in step 520 the controller microcomputer 402 (FIG. 4) determines that there is at
15 least one available adjacent transceiver 202 (FIG. 2), then the controller microcomputer 402 sends 524 a message to the microcomputer 204 (FIG. 2) of each fixed communication unit 102 (FIG. 1) near the first fixed communication unit 102 that has an available transceiver 202, the message
20 identifying the portable communication unit 120 (FIG. 1) and commanding the microcomputer 204 to tune the available transceiver 202 to the original channel and monitor the RSSI resulting from transmissions received from the portable communication unit. 120. In response, the
25 microcomputer 204 first verifies 526 the identity of the portable communication unit 120 sending any receivable transmission, and if the identity matches the identity sent in the message from the controller microcomputer 402, then the microcomputer 204 reads and reports to the controller
30 microcomputer 402 a value received from the RSSI circuit 216 (FIG. 2), provided that the value is above a pre-determined threshold.

To allow time for all fixed communication units 102 (FIG. 1) to monitor transmissions and then report, the
35 controller microcomputer 402 (FIG. 4) delays 528 before checking 530 to determine whether any fixed communication units 102 have responded. If there is at least one response, the controller microcomputer 402 then designates

532 the responding fixed communication unit 102 having the highest reported RSSI as the receiving fixed communication unit 102, and the flow continues to step 602 of FIG. 6.

If, on the other hand, there is no response found in step 530, then the controller microcomputer 402 sends 522 a message back to the microcomputer 204 of the first fixed communication unit 102. The message instructs the microcomputer 204 to send a message to the portable communication unit 120 for generating an audible indication to inform the user that the user is going out of transmission range and should stop moving.

With reference to FIG. 6, the flow chart of a method of performing a hand-off in accordance with the preferred embodiment of the present invention continues with the controller microcomputer 402 (FIG. 4) accessing 602 the channel database 404 (FIG. 4) to determine what channels are available to the receiving fixed communication unit 102 (FIG. 1). In making the determination the controller microcomputer 402 first checks 604 whether the original channel can be used without generating or receiving co-channel, adjacent channel, or intermodulation interference with or from other channels currently in use by other fixed communication units 102 indicated by the channel database 404 to be physically near the receiving fixed communication unit 102. If in step 606 the controller microcomputer 402 determines that the original channel can be used, then the controller microcomputer 402 defines 608 the original channel to be the "optimum channel," and then the flow moves to step 702 of FIG. 7.

If, on the other hand, the controller microcomputer 402 (FIG. 4) determines in step 606 that the original channel cannot be used, then the controller microcomputer 402 uses the channel selector 406 (FIG. 4) to select 610 a channel that is most likely not to generate or receive co-channel, adjacent channel, or intermodulation interference with or from other channels currently in use by other fixed communication units 102 (FIG. 1) and indicated by the channel database 404 (FIG. 4) to be physically near the

receiving fixed communication unit 102. Next, the controller microcomputer 402 defines 612 the selected channel to be the "optimum channel," and then the flow moves to step 702 of FIG. 7.

5 With reference to FIG. 7, the flow chart of a method of performing a hand-off in accordance with the preferred embodiment of the present invention continues with the controller microcomputer 402 (FIG. 4) commanding 702 the digital switch 418 (FIG. 4) to couple digitized audio of
10 the call from the one of the CODECs 422 (FIG. 4) that is handling the call to the one of the DNICs 416 (FIG. 4) that is coupled to the receiving fixed communication unit 102. Next, the controller microcomputer 402 checks 704 whether it has defined the optimum channel to be the original
15 channel.

 If so, the controller microcomputer 402 commands 712 the microcomputer 204 (FIG. 2) of the receiving fixed communication unit 102 (FIG. 1) to control the receiving fixed communication unit 102 to begin transceiving
20 synchronously with the portable communication unit 120 (FIG. 1) at a specified subsequent fixed communication unit receive-to-transmit transition on the original channel. Immediately thereafter, the controller microcomputer 402 also commands 714 the microcomputer 204 of the first fixed
25 communication unit 102 to control the receiving fixed communication unit 102 to end transceiving with the portable communication unit 120 at the specified subsequent fixed communication unit receive-to-transmit transition. When the first fixed communication unit 102 and the
30 receiving fixed communication unit 102 comply 716 by simultaneously ending and beginning, respectively, transceiving, a substantially seamless hand-off takes place. As a final action, the controller microcomputer 402 commands 718 the digital switch 418 to uncouple the first
35 fixed communication unit 102 from the call, and the hand-off is complete 720.

 The method in which the optimum channel is defined to be the original channel as just described in the preceding

paragraph is preferred, because it produces a substantially seamless hand-off, i.e., a hand-off that substantially eliminates any gap in communications and thus is substantially unnoticeable to the user. Still,

5 interference conditions sometimes make it impossible to define the optimum channel to be the original channel, and the method described in the following paragraph must be used.

If in step 704 the controller microcomputer 402 (FIG. 4) determines that it has not defined the original channel to be the optimum channel, then the controller microcomputer 402 commands 706 the microcomputer 204 (FIG. 2) of the receiving fixed communication unit 102 (FIG. 1) to control the receiving fixed communication unit 102 to monitor the optimum channel for a link request from the portable communication unit 120 (FIG. 1). Next, the controller microcomputer 402 commands 708 the microcomputer 204 of the first fixed communication unit 102 to send a link re-establishment message identifying the optimum channel to the portable communication unit 120. In response, the microcomputer 204 of the first fixed communication unit sends 710 the message to the portable communication unit 120 over the wireless link with the portable communication unit 120 on the original channel. The portable communication unit 120 complies with the message by linking with the receiving fixed communication unit 102 on the optimum channel. Then, as before, the controller microcomputer 402 commands 718 the digital switch 418 to uncouple the first fixed communication unit 102 from the call, and the hand-off is complete 720.

While the method of handing-off to a new channel as just described in the preceding paragraph does not produce the preferred substantially seamless hand-off possible when remaining on the original channel, the method does provide a hand-off having a communications gap of less than 300 milliseconds. In voice communications a hand-off gap of 300 milliseconds is considered barely noticeable, provided that the gap occurs infrequently, as is true for hand-off.

In data communications there are many well-known retransmission techniques for recovering data lost during such brief gaps. Thus, the hand-off method according to the present invention advantageously provides a hand-off
5 that is substantially seamless whenever possible, and very nearly seamless when conditions prevent the substantially seamless hand-off.

With reference to FIG. 8, a flow chart of an alternate embodiment of the portion of the flow chart depicted in
10 FIG. 6 in accordance with the present invention begins with the controller microcomputer 402 (FIG. 4) accessing the channel database 404 (FIG. 4) to determine whether the original channel is being used by another fixed
communication unit 102 (FIG. 1) (other than the first fixed
15 communication unit 102) near the receiving fixed communication unit 102. If not 804, then the controller microcomputer 402 defines 806 the original channel to be the "optimum channel," and flow continues with step 702 of
FIG. 7. If in step 804 the controller microcomputer 402
20 finds that the original channel is in use, then the controller microcomputer 402 commands 808 the microcomputer 204 (FIG. 2) of the receiving fixed communication unit 102 to find and report a new channel for receiving the hand-off. The microcomputer 204 controls the receiving fixed
25 communication unit 102 to scan 810 all possible channels and report a new channel having the lowest RSSI. As a final step, the controller microcomputer 402 defines the reported new channel to be the "optimum channel," and flow continues with step 702 of FIG. 7.

30 Thus, the present invention provides a way of performing a hand-off in a CT2 system that allows confirmation of the source of a signal while synchronously monitoring the signal level to select the best fixed communication unit for receiving the hand-off. By
35 maintaining a common synchronization among all fixed communication units and portable communication units in the system, the present invention allows any of the fixed communication units within receiving range to monitor

communications from and even to begin transceiving with a portable communication unit to effect a hand-off while the portable communication unit is transceiving user data. It is impossible to do such monitoring and hand-off in a CT2 system without the present invention. This new ability enables a substantially seamless hand-off to occur when channel usage in nearby cells allows a call to remain on the original channel after the hand-off, and enables a nearly seamless hand-off to occur even when channel usage requires moving the call to a new channel.

What is claimed is:

CLAIMS

1. A method in a plurality of fixed communication units for performing a hand-off from an original channel in a wireless communication system comprising a portable communication unit and a controller coupled to the plurality of fixed communication units, the method comprising the steps of:

(a) receiving from the controller a common master synchronization signal;

(b) receiving from the controller a request to monitor receivable transmissions from the portable communication unit on the original channel; and

(c) performing in response to step (b) synchronous monitoring of the receivable transmissions from the portable communication unit on the original channel, the synchronous monitoring being synchronized by the common master synchronization signal.

2. The method in accordance with claim 1, further comprising the steps of:

(d) measuring received signal strength of the receivable transmissions from the portable communication unit monitored synchronously in step (c); and

(e) reporting to the controller the measured received signal strength in response to the measured received signal strength being greater than a pre-determined amount.

3. A method in one of a plurality of fixed communication units for obtaining a hand-off from an original channel in a wireless communication system comprising a portable communication unit and a controller coupled to the plurality of fixed communication units, the method comprising the steps of:

(a) receiving a common master synchronization signal transmitted from the controller; and

(b) establishing a wireless link with the portable communication unit on the original channel, the link being synchronized with the master synchronization signal.

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4. The method in accordance with claim 3, further comprising the steps of:

(c) periodically monitoring received signal strength from the portable communication unit with which the wireless link is established; and

10

(d) transmitting a hand-off request to the controller in response to determining in step (c) that the received signal strength is less than a pre-determined level.

15

5. The method in accordance with claim 4, further comprising the steps of:

(e) receiving from the controller in response to step (d) a command to send a link re-establishment message for a new channel with a new channel identifier to the portable communication unit; and

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(f) sending in response to step (e) the link re-establishment message and the new channel identifier to the portable communication unit.

25

6. The method in accordance with claim 4, further comprising the steps of:

(g) receiving from the controller in response to step (d) a command to stop sending radio transmissions to the portable communication unit; and

30

(h) terminating radio transmissions to the portable communication unit in response to step (g).

7. The method in accordance with claim 4, further comprising the steps of:

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(i) receiving a hand-off denial message from the controller in response to step (d); and

(j) sending an audible indication to the portable communication unit in response to step (i).

8. A method in one of a plurality of fixed communication units for receiving a hand-off from an original channel in a wireless communication system comprising a portable communication unit and a controller coupled to the plurality of fixed communication units, the method comprising the steps of:
- (a) receiving from the controller a common master synchronization signal;
 - (b) receiving from the controller a request to monitor receivable transmissions from the portable communication unit on the original channel; and
 - (c) performing in response to step (b) synchronous monitoring of the receivable transmissions from the portable communication unit on the original channel, the synchronous monitoring being synchronized by the common master synchronization signal.

20

9. The method in accordance with claim 8, further comprising the step of:

- (d) measuring received signal strength of the receivable transmissions from the portable communication unit monitored synchronously in step (c); and
- (e) reporting to the controller the measured received signal strength in response to the measured received signal strength being greater than a pre-determined amount.

30

10. The method in accordance with claim 8, further comprising the steps of:

- (f) receiving from the controller a command to find a channel for accepting the hand-off;
- (g) measuring the received signal strength on a plurality of channels in response to step (f); and

35

(h) selecting the one of the plurality of channels measured in step (g) having the lowest received signal strength; and

(i) identifying to the controller the channel
5 found in step (g).

11. The method in accordance with claim 8, further comprising the steps of:

(j) monitoring a channel identified by the
10 controller for a link request from the portable communication unit, the channel identified being different from the original channel; and

(k) beginning radio transmissions immediately on the channel identified by the controller, the channel
15 identified being the original channel.

12. A method for performing a hand-off from an original channel in a wireless communication system comprising a portable communication unit and a controller coupled to a
20 plurality of fixed communication units, the method comprising the steps of:

(a) sending a common master synchronization signal from the controller to the plurality of fixed communication units;

25 (b) receiving a hand-off request sent from a first one of the plurality of fixed communication units;

(c) sending in response to step (b) from the controller to the plurality of fixed communication units a request to synchronously monitor receivable transmissions
30 from the portable communication unit on the original channel, the synchronous monitoring being synchronized by the common master synchronization signal sent in step (a);

(d) receiving in response to step (c) signal strength measurements sent from ones of the plurality of
35 fixed communication units; and

(e) handing-off a call from the first one of the plurality of fixed communication units to a second one of

the plurality of fixed communication units having sent the highest signal strength measurement in step (d).

13. The method in accordance with claim 12, wherein
5 step (e) comprises the steps of:

(f) determining an optimum channel to use for the hand-off;

(g) coupling a second digital communication path between the call and the second one of the plurality of
10 fixed communication units;

(h) commanding the second one of the plurality of fixed communication units to monitor for a link request message on the optimum channel determined in step (f), the optimum channel being different from the original channel;

15 (i) commanding in response to executing step (h) the first one of the plurality of fixed communication units to send a link re-establishment message identifying the optimum channel to the portable communication unit;

(j) commanding the first and second ones of the
20 plurality of fixed communication units to end and begin, respectively, radio transmissions simultaneously with the start of a designated future frame, the optimum channel being the same as the original channel; and

(k) uncoupling the call from the first one of the
25 plurality of fixed communication units in response to determining completion of the hand-off.

14. The method in accordance with claim 13, wherein step (f) comprises the steps of:

30 (l) commanding the second one of the plurality of fixed communication units to measure received signal strength on a plurality of channels and to report the one of the plurality of channels having the lowest measured received signal strength;

35 (m) receiving in response to step (l) from the second one of the plurality of fixed communication units a report of the one of the plurality of channels having the lowest measured received signal strength; and

(n) defining the reported one of the plurality of channels reported in step (m) to be the optimum channel to use for the hand-off.

5 15. The method in accordance with claim 13, wherein step (f) comprises the steps of:

(o) maintaining a current record of the in-use channels and the available channels for ones of the plurality of fixed communication units;

10 (p) selecting from the available channels for the second one of the plurality of fixed communication units a channel that minimizes interference with channels currently in use by ones of the plurality of fixed communication units within interfering range of the second one of the
15 plurality of fixed communication units.

16. The method in accordance with claim 15, wherein step (p) comprises the steps of:

(q) avoiding channels currently in use by ones of
20 the plurality of fixed communication units within co-channel interfering range of the second one of the plurality of fixed communication units;

(r) avoiding channels adjacent to channels currently in use by ones of the plurality of fixed
25 communication units within adjacent-channel interfering range of the second one of the plurality of fixed communication units; and

(s) avoiding channels that will produce interfering intermodulation products with channels
30 currently in use by ones of the plurality of fixed communication units within intermodulation interfering range of the second one of the plurality of fixed communication units.

35 17. An apparatus in a controller for performing a hand-off in a wireless communication system comprising a portable communication unit and the controller coupled to a

plurality of fixed communication units, the apparatus comprising:

synchronization means for generating a common master synchronization signal for the plurality of fixed communication units;

controller interface means coupled to the synchronization means for interfacing with ones of the plurality of fixed communication units;

telephone interface means for interfacing the controller to a telephone system;

switch means for handing-off a call from a first one of the plurality of fixed communication units to a second one of the plurality of fixed communication units; and

channel optimization means for optimizing the selection of a channel for the hand-off.

18. The apparatus according to claim 17, wherein the channel optimization means comprises:

data base means for maintaining a current record of the in-use channels and the available channels for ones of the plurality of fixed communication units; and

channel selection means for selecting from the available channels for the second one of the plurality of fixed communication units a channel that minimizes interference with channels currently in use by ones of the plurality of fixed communication units within interfering range of the second one of the plurality of fixed communication units, wherein the channel selection means comprises:

co-channel avoidance means for avoiding channels currently in use by ones of the plurality of fixed communication units within co-channel interfering range of the second one of the plurality of fixed communication units;

adjacent-channel avoidance means for avoiding channels adjacent to channels currently in use by ones of the plurality of fixed communication units within

adjacent-channel interfering range of the second one of the plurality of fixed communication units; and

intermodulation-channel avoidance means for avoiding channels that will produce interfering

- 5 intermodulation products with channels currently in use by ones of the plurality of fixed communication units within intermodulation interfering range of the second one of the plurality of fixed communication units.

- 10 19. An apparatus in a fixed communication unit for performing a hand-off in a wireless communication system comprising a portable communication unit and a controller coupled to a plurality of fixed communication units, the apparatus comprising:

- 15 synchronization means for synchronizing with a common master synchronization signal transmitted from the controller; and

- wireless link establishment means coupled to the synchronization means for establishing a wireless link with
20 the portable communication unit, the link being synchronized with the master synchronization signal; and

- synchronous monitoring means coupled to the synchronization means for synchronously monitoring receivable transmissions from the portable communication
25 unit.

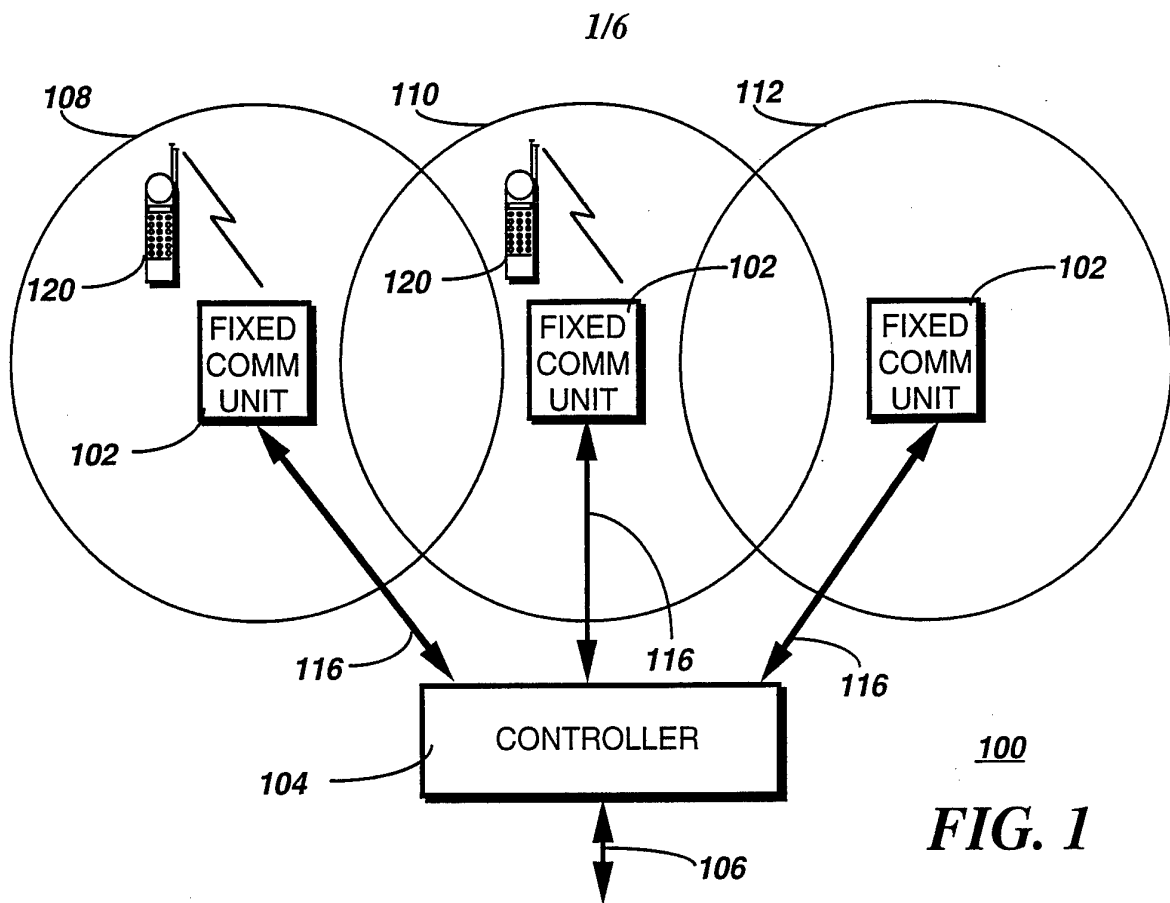
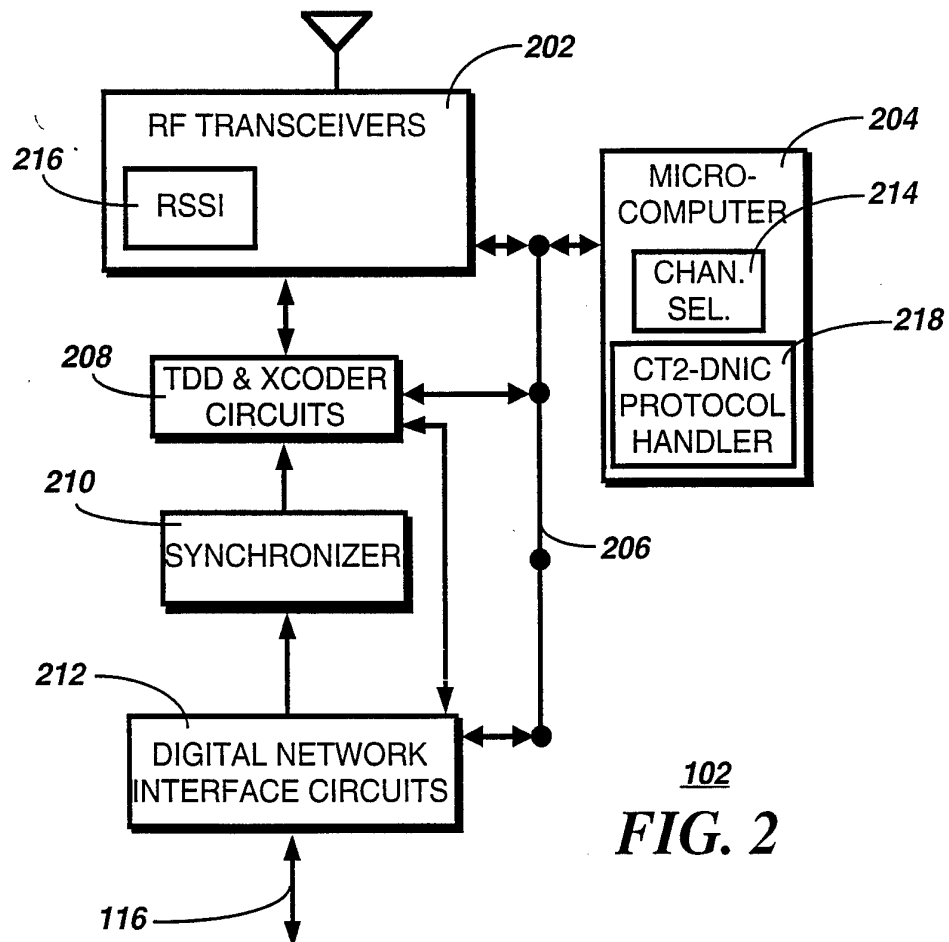
20. The apparatus in accordance with claim 19, further comprising:

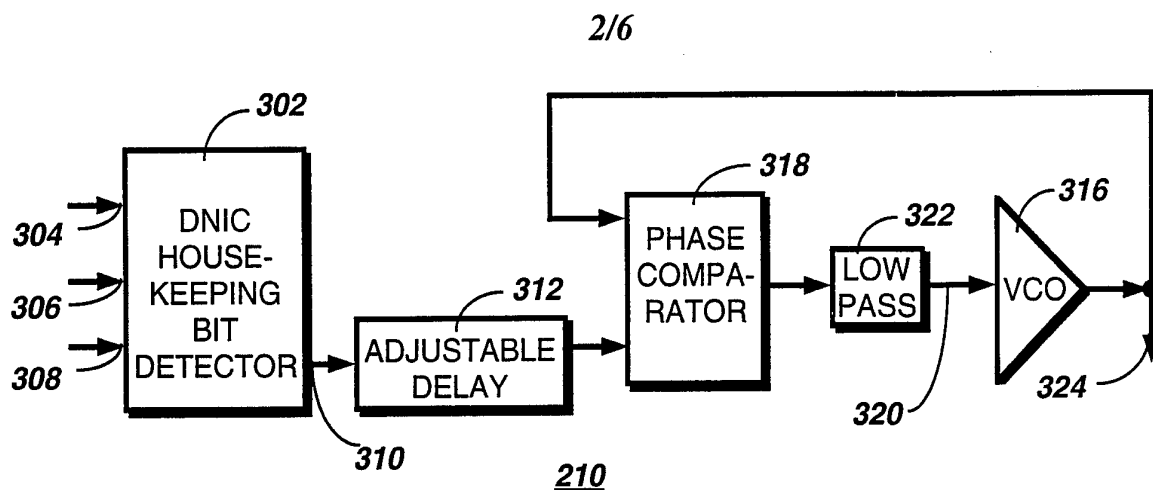
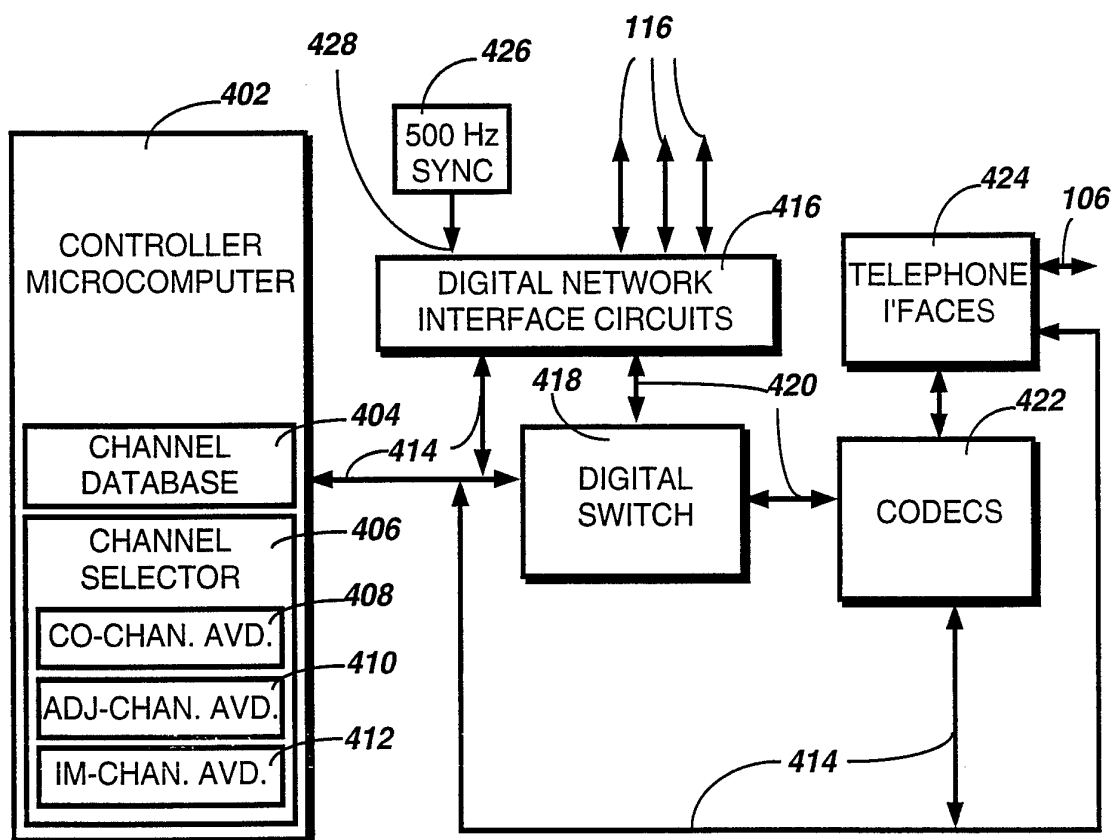
- controller interface means coupled to the
30 synchronization means for interfacing with the controller;
transceiver means coupled to the synchronization means for transmitting and receiving information to and from the portable communication unit; and
processor means coupled to the controller
35 interface means and to the transceiver means for controlling the fixed communication unit.

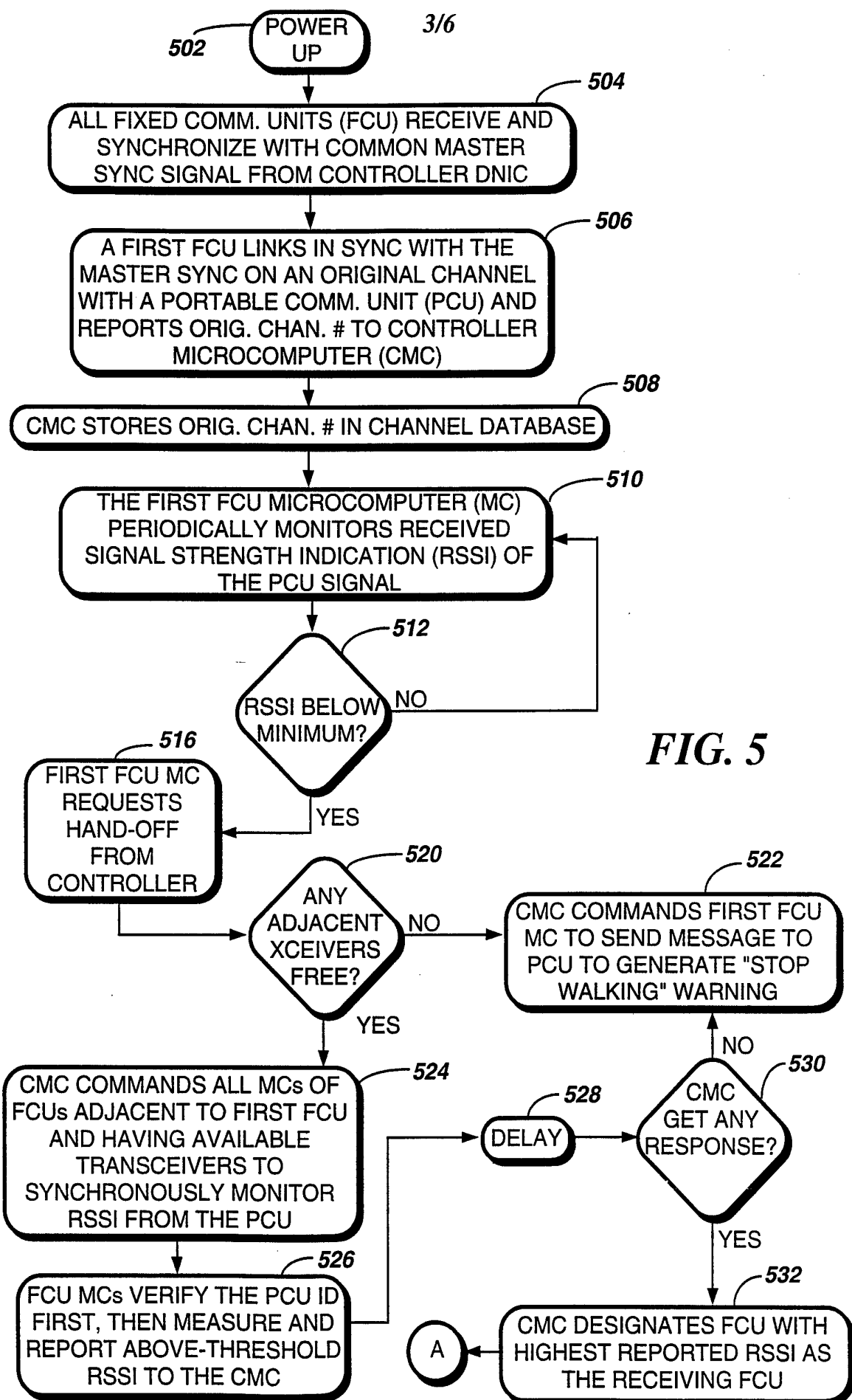
21. The apparatus in accordance with claim 19, further comprising:

received signal strength measurement means for measuring the signal strength of a received signal; and

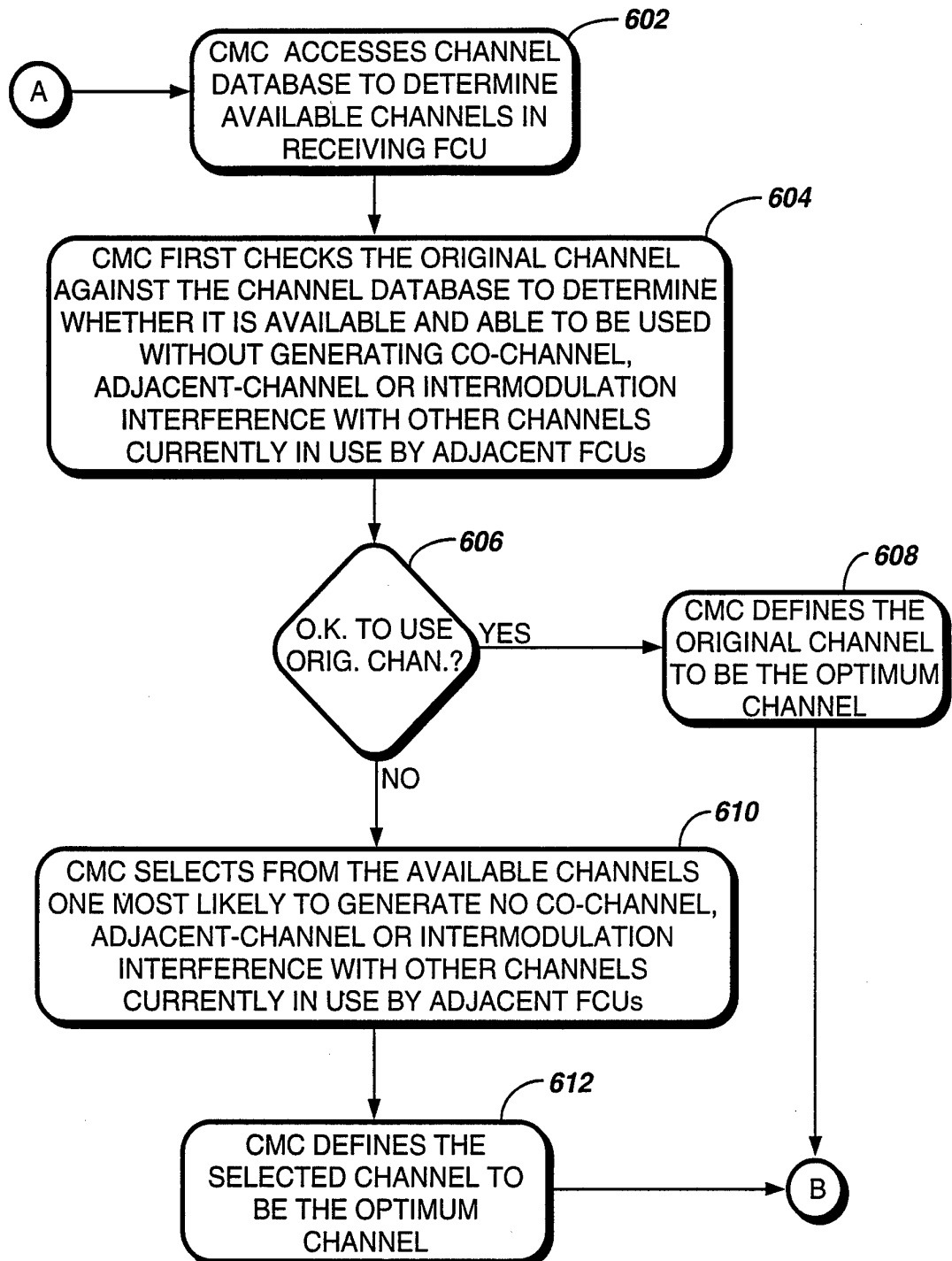
5 channel selection means coupled to the received signal strength measurement means for selecting a channel having the lowest received signal strength measurement.

**FIG. 1****FIG. 2**

**FIG. 3****FIG. 4**



4/6

**FIG. 6**

5/6

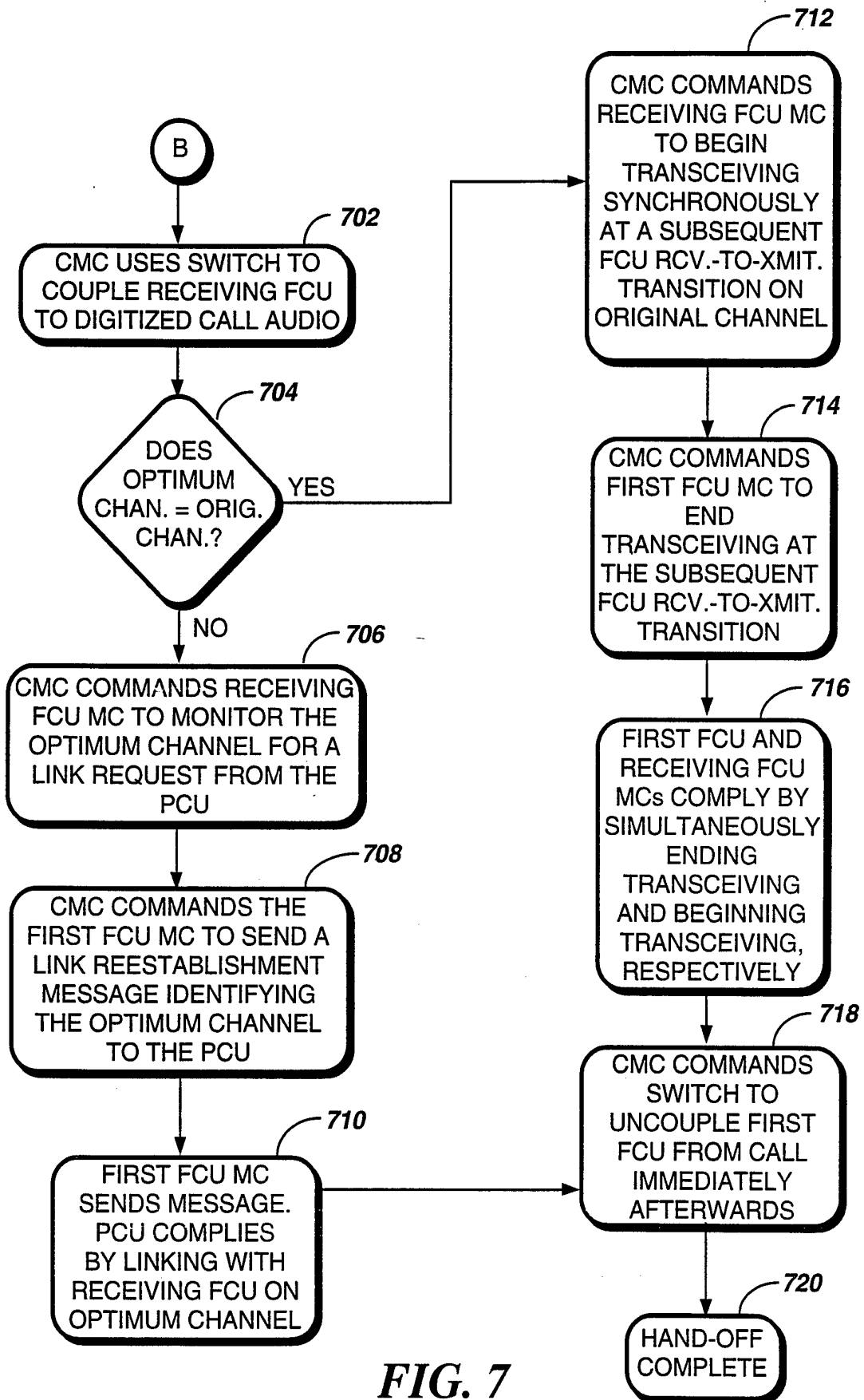


FIG. 7

6/6

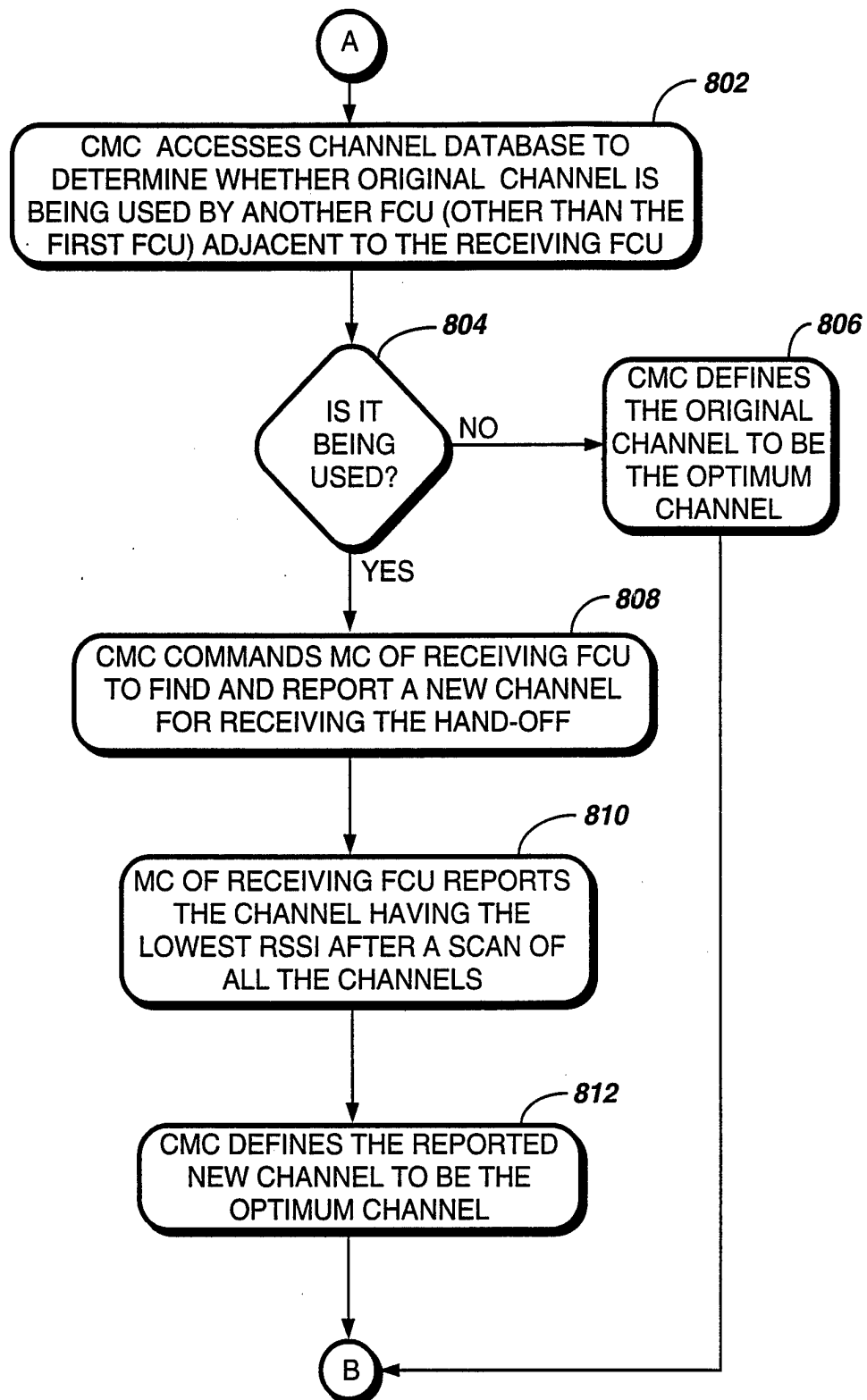
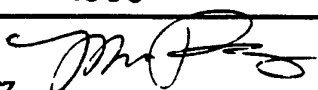


FIG. 8

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US93/06978

A. CLASSIFICATION OF SUBJECT MATTER IPC(5) : HO4M 11/00 US CL : 379/63 According to International Patent Classification (IPC) or to both national classification and IPC				
B. FIELDS SEARCHED Minimum documentation searched (classification system followed by classification symbols) U.S. : 379/63, 58, 60; 455/33.2, 34.1, 34.2, 51.1, 56.1, 54.1 Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)				
C. DOCUMENTS CONSIDERED TO BE RELEVANT				
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.		
Y,E	US, A, 5,243,653 (Malek et al) 07 September 1993, col 2 lines 25-30.	1-21		
Y,E	USA, A, 5,239,676 (Strawczynski et al) 24 August 1993, Fig 4a, Fig 4b, col 2 lines 25-48, col 3 lines 3-9.	1-21		
Y	US, A, 4,654,867 (Labeledz et al) 31 March 1987, col 10 lines 3-21 and 43-48.	7		
Y, &	US, A, 5,203,012 (Patsiokas et al) 13 April 1993, claims 3-4.	16,18		
<input type="checkbox"/> Further documents are listed in the continuation of Box C. <input type="checkbox"/> See patent family annex.				
<table border="0"> <tr> <td> * Special categories of cited documents: "A" document defining the general state of the art which is not considered to be part of particular relevance "E" earlier document published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed </td> <td> "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art "A" document member of the same patent family </td> </tr> </table>			* Special categories of cited documents: "A" document defining the general state of the art which is not considered to be part of particular relevance "E" earlier document published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed	"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art "A" document member of the same patent family
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Date of the actual completion of the international search 15 SEPTEMBER 1993		Date of mailing of the international search report 01 NOV 1993		
Name and mailing address of the ISA/US Commissioner of Patents and Trademarks Box PCT Washington, D.C. 20231 Facsimile No. NOT APPLICABLE		Authorized officer  CURTIS KUNTZ Telephone No. (703) 305-4708		