INTEGRATED DIGITAL TRUNK FRAME CARD WITH ECHO CANCELLATION AND BACKWARD COMPATIBILITY

Abstract: An embodiment of the invention includes an integrated digital trunk frame (DTF) card including a matrix interface for interfacing with a switch having a first port for receiving signals in a first transmission direction from the switch, a second port for transmission signals in a second transmission direction opposite the first transmission direction to the switch, a third port for transmitting the received signals in the first direction and a fourth port for receiving signals in the second direction; an echo cancellation device having a first port for receiving the signals transmitted in the first direction from the third port of the matrix interface. An echo cancellation controller provides control signals to the echo cancellation device.
INTEGRATED DIGITAL TRUNK FRAME CARD WITH ECHO CANCELLATION AND BACKWARD COMPATIBILITY

BACKGROUND OF THE INVENTION

Technical Field

The present invention is related to the field of telecommunications network systems. More specifically, the present invention is related to a digital trunk frame system integrated with echo cancellation while maintaining backward compatibility with installed equipment.

Description of the Related Art

Echo cancellation in telecommunications systems has proven to be an expensive problem to solve. Echo occurs in an analog telephone line because the use of hybrid transformers to connect the standard two-wire connection from the customer’s telephone to a four-wire system with separate send and receive wire pairs. The four-wire system is required when any significant transmission length is required. In practice, this is virtually every analog telephone line.

The echo occurs because of impedance mismatches between the hybrid transformer’s inputs and the four and two-wire lines connected to it. An additional source of echo is simple cross-talk. During a cross-town call, the echo is not noticeable and even enhances the perceived quality of the signal. However, over longer distances, the echo can make holding a normal conversation difficult.

This problem has been recognized for some time. Campanella et al. (U.S. Patent No. 3,894,200) show an echo cancellation system for long distance systems. Today, it is common practice to include an echo cancellation system on long distance trunk lines.

Typically, a local exchange carrier sends PCMI encoded signals along with routing information to a long distance switching center. The long distance switching center typically includes control and routing circuitry. These are connected to the long distance trunk lines using a digital trunk frame (DTF). The DTF includes a large number of slots to receive digital trunk interface cards containing the interface circuitry between the switching system and the trunk line driving electronics. DTF cards typically include a control interface that allows the control circuitry to issue commands and receive data from the DTF cards. The
software that operates the control circuitry and communicates with the DTF cards is very sophisticated and expensive to produce and maintain.

The echo cancellation systems are commonly installed in a separate frame. This facilitates providing selective use of echo cancellation. Echo cancellation is generally only provided for long distance trunk lines. For each long distance trunk line, a line runs from the DTF card to an echo cancellation circuit. The echo cancellation circuit then is connected to the trunk line driving circuitry. The output of the DTF card is typically in a format for transmission, such as the American National Standards Institute (ANSI) T1 standard. However, to perform echo cancellation the signal must be converted to a lower level digital signal such as PCM. After echo cancellation, the signal must be converted back to a T1 signal.

As explained above, echo cancellation is installed separately allow selective provision of echo cancellation to those trunk lines where it is required. An additional benefit of separate installation is that it avoids the need to rewrite the control software of the switching control system to accommodate echo cancellation control. However, the separate frame, power supplies and the conversion to and from the transmission standard requires echo cancellation systems that are expensive to install and maintain. There is a need in the industry for an echo cancellation system that includes full control, does not require revision of the control systems of the switching center but does not require expense of separate installation.

**BRIEF SUMMARY OF THE INVENTION**

It is an object of the present invention to provide an integrated echo cancellation function that allows for separate control of the echo cancellation function.

It is a further object to provide an integrated echo cancellation function that does not require an additional frame or conversion circuitry.

These and other objects are achieved by the present invention. An embodiment of the invention includes an integrated DTF card comprising: a matrix interface for interfacing with a switch having a first port for receiving signals in a first transmission direction from the switch, a second port for transmitting signals in a second transmission direction opposite the first transmission direction to the
switch, a third port for transmitting the received signals in the first direction and a
fourth port for receiving signals in the second direction; an echo cancellation device
having a first port for receiving the signals transmitted in the first direction from the
third port of the matrix interface, a second port for transmitting the signals
transmitted in the second direction to the fourth port of the matrix interface, a third
port for transmitting the received signals in the first direction and a fourth port for
receiving signals in the second direction, the echo cancellation device providing
echo cancellation in the signals transmitted in the first and second directions; a
trunk interface for interfacing with a trunk distribution line having a first port for
receiving signals in the first transmission direction from the echo cancellation
device, a second port for transmitting signals in the second transmission direction
to the echo cancellation device, a third port for transmitting the received signals in
the first direction to a trunk transmission line and a fourth port for receiving signals
in the second direction from the trunk transmission line; an echo cancellation
controller providing control signals to the echo cancellation device; a memory for
storing data and control software in communication with the echo cancellation
controller; and a terminal interface for receiving control signals from an external
terminal to the echo cancellation controller and providing status signals from the
echo cancellation controller to the external terminal.

BRIEF DESCRIPTION OF THE DRAWINGS

For a more complete understanding of the present invention and the
advantages thereof, reference should be made to the following Detailed Description
taken in conjunction with the accompanying drawings in which:

Figure 1 is a block diagram of a simplified trunk line transmission system;

Figure 2 is a block diagram of a prior art trunk interface system including
echo cancellation;

Figure 3 is a block diagram of a prior art DTF card;

Figure 4 is a block diagram of a prior art echo cancellation card;

Figure 5 is drawing depicting a typical installation of DTF frames and their
connection to an echo cancellation frame and a multiplexer;

Figure 6 is a digital trunk interface card which is an embodiment of the
present invention; and
**Figure 7** is a block diagram of a DTF installation using an embodiment of the present invention.

**DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT**

**Figure 1** is a block diagram of a simplified trunk transmission network. Local exchange 12 is connected to trunk switching center 14 for connection to a long distance network. Trunk line 15 connects trunk switching center 14 to trunk switching center 16. Trunk switching center 16 is then connected to local exchange 18. If a customer on local exchange 12 makes a call to another customer on local exchange 18, the call is routed through trunk switching center 14, over trunk line 15, through trunk switching center 16 to local exchange 18. Trunk line 15 is a high capacity digital line such as a fiber optic line transmitting using the ITU OC3 standard. Of course, the diagram of **Figure 1** is greatly simplified. An actual network would include hundreds of interconnected trunk switching centers.

**Figure 2** is a block diagram showing the structure of a trunk switching center as configured using conventional techniques. Local exchange 12 is connected to a switch 22 for routing calls. Switch 22 may be one of a number of switching products available from manufacturers such as Lucent Technologies®, Nortel Networks® or Alcatel®. Switch 22 is connected to a plurality of digital trunk interface (DTI) cards 26 in a digital trunk frame (DTF) 24. DTI cards 26 provide an interface to each trunk-bound output from switch 22. Generally, the signal provided by switch 22 is in pulse code modulated interface (PCMI) format. The output of DTI cards 26 is in a format suitable for trunk line transmission. For example, a common output is the ANSI T1 standard. DTI cards 26 provide the conversion from PCMI to T1.

To provide echo cancellation, the T1 output is provided to an echo cancellation card 30. An echo cancellation card is provided for each long distance trunk line output from DTF 24. Echo cancellation cards 30 are provided in a separate frame 28 from DTF 24 to allow for separate control functionality to DTI cards 26 and echo cancellation cards 30 and flexibility in applying echo cancellation to selected trunk lines. In the industry standard configurations, control signals for the DTI cards 26 are provided from switch 22 through DTF 24. Control
to echo cancellation cards 30 for reconfiguration, tuning and analysis is provided through frame 28.

**Figure 3** is a block diagram showing the functional units of DTI card 26. Also shown is a functional block diagram of switch 22. Switch 22 consists of a switching matrix 42 under the control of processor 44. Switching matrix 42 provides the routing of calls. The routing may include routing from trunk line to trunk line, trunk line to local exchange or local exchange to trunk line. Processor 44 provides control functions and includes the complex software necessary to operate the switch 22.

For each trunk line, a DTI card 26 is provided. DTI card 26 includes a matrix interface 48 that receives PCMI encoded signals from switching matrix 42 via two-way line 46. Matrix interface 48 provides signal buffering and some signal conversion and processing. Matrix interface 48 provides pulse code modulated (PCM) signal to T1 interface 50 via two-way line 47. T1 interface 50 converts the PCM signal to T1 signals by adding formatting and control signals. The resulting T1 signal is provided on output line 52. Matrix interface 48 and T1 interface 50 operate under the control of signals provided by processor 44 via processor interface 54.

The output of the DTI card 26 is provided to echo cancellation card 30 via line 52. As shown in **Figure 4**, the T1 signal provided on line 52 is provided to T1 to PCM converter 54. This conversion is necessary to allow echo processor 58 to properly provide echo cancellation. The PCM signal is provided to echo processor 58 from converter 54 via two-way line 56. Typically, an echo cancellation device includes one or more digital signal processors programmed to provide the echo cancellation function. The signals on the two-way lines are compared to discern the presence of echo, determine an appropriate cancellation signal for addition to the signals and execute the signal addition to remove the echo from the signals. An example of such a system is shown in Sih, U.S. Patent No. 5,307,405. Two-way line 60 provides the PCM signal to, from echo processor 58 from, to PCM to T1 converter 62. Output line 64 then provides the converted T1 signal to multiplexer 32 (Figure 2).
Figure 5 is a depiction of the physical cabinetry involved in the system of Figure 2. Typically, DTF 24 consists of several frames populated by hundreds of DTI and other type cards. Wiring from each DTI card must be provided to each echo cancellation card in frame 28. Frame 28 includes a separate power supply system and control buses.

Figure 6 is a block diagram of an integrated digital trunk interface card that is an embodiment of the present invention. Matrix interface 110 receives signals from a switching matrix, such as switching matrix 42 of Figure 3, via two-way line 112. Matrix interface 110 provides buffering functions and converts PCMI signals to and from PCM. The converted signals are transmitted to digital signal processors 116 via two-way line 114. In the preferred embodiment, two digital signal processors are used, such as TMS320C548 DSPs available from Texas Instruments Incorporated. Software for programming DSPs 116 to provide an echo cancellation function is available commercially from vendors such as Echelon Corporation. DSPs 116 operate under the control of host controller 118. Host controller 118 sends and receives control signals configuring and controlling the operation of DSPs 116. Random access memory (RAM) 120 and electrically erasable programmable read-only memory (EEPROM) 122 provide data storage for host controller 118.

On initial power up, the software for DSPs 116 is stored in EEPROM 122. A power-up routine for host controller 118 (also stored in EEPROM 122) causes the DSP software to be loaded into the DSPs internal registers and memory to initiate the echo cancellation function. In addition, host controller periodically "pings" DSPs 116 to ensure that they are operating properly. Host controller 118 can provide instructions directly or through control logic 124. Control logic 124 is a programmable gate array programmed to handle simpler functions. This reduces some of the load on host controller 118. Host controller is preferably a microcontroller such as those provided by Intel®, Hitachi® and others.

Control functions can also be provided by the switch controller 44 (Figure 3) provided through processor interface 126. However, it is preferable to have all off card control functions be performed by host controller 118 under the control of
programs and instructions provided from terminal 128 through terminal interface 130.

Terminal 128 is preferably a hand held terminal connected to each DTI card 100 via a front panel plug 132. However, any device capable of transmitting control signals can provide this function, such as a personal computer. Software for both host controller 118 and DSPs 116 can be downloaded from terminal 128. A wide range of echo cancellation parameters can be controlled via terminal 128.

A partial list includes:

<table>
<thead>
<tr>
<th>Common Parameters (Affects all channels on a T1 line)</th>
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</thead>
<tbody>
<tr>
<td>Idle Settings</td>
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<tr>
<td>Idle Pattern Selection</td>
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<tr>
<td>Signaling Pattern</td>
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<tr>
<td>Idle Direction</td>
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<tr>
<td>NLP Settings</td>
</tr>
<tr>
<td>NLP Re-enable</td>
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<tr>
<td>Noise Matching</td>
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<tr>
<td>Direction Settings</td>
</tr>
<tr>
<td>Input Options</td>
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<tr>
<td>Output Options</td>
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</tbody>
</table>
Channel Parameters (Controllable on a per-channel basis)

<table>
<thead>
<tr>
<th>Feature</th>
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</thead>
<tbody>
<tr>
<td>Loopback Setting</td>
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<tr>
<td>Transparent Bypass Setting</td>
</tr>
<tr>
<td>Maximum Tail Delay</td>
</tr>
<tr>
<td>Residual Echo Control</td>
</tr>
<tr>
<td>H Register Hold (testing only)</td>
</tr>
<tr>
<td>Modem Tone Disable Setting</td>
</tr>
<tr>
<td>Re-enable Setting</td>
</tr>
<tr>
<td>Switched 56K Setting</td>
</tr>
<tr>
<td>Echo Return Loss Setting</td>
</tr>
<tr>
<td>Signaling Setting</td>
</tr>
<tr>
<td>High-Level Compensation Setting</td>
</tr>
<tr>
<td>Digital Milliwatt Setting</td>
</tr>
</tbody>
</table>

In addition, control signals can be provided from host controller 118 to terminal 128 to allow display of settings and performance criteria. Because DSPs 116 provide the echo cancellation function by mathematical operation on digital PCM signals, virtually any performance criterion may be calculated and provided via terminal 128. In addition, because control and monitoring functions are provided through terminal 128, no modification to the software operating on switch processor 44 is necessary. Thus, inexpensive backward compatibility is provided by DTI card 100.

Figure 7 shows a trunk switching center using DTI card 100. Switch 22 communicates the cards in DTF 24. Because echo cancellation is provided by DTI card 100, no separate echo cancellation frame is necessary. The T1 output of DTI card 100 is provided directly to multiplexer 32 for transmission on line 15. Thus the use of DTI card 100 eliminates the need for an entire frame installation while avoiding the need to modify the switching center software to accommodate echo cancellation in the DTF 24.
Although specific embodiments of the present invention are disclosed herein, they are not to be construed as limiting the scope of the present invention. For example, although the invention is herein described with regard to a local exchange connection to a trunk switching center, it may also be advantageously used in a wireless telephone switching center. The scope of the present invention is only limited by the claims appended hereto.
CLAIMS

1. An integrated digital trunk interface card comprising:
   a matrix interface for interfacing with a switch having a first port for receiving signals in a first transmission direction from the switch, a second port for transmitting signals in a second transmission direction opposite the first transmission direction to the switch, a third port for transmitting the received signals in the first direction and a fourth port for receiving signals in the second direction;
   an echo cancellation device having a first port for receiving the signals transmitted in the first direction from the third port of the matrix interface, a second port for transmitting the signals transmitted in the second direction to the fourth port of the matrix interface, a third port for transmitting the received signals in the first direction and a fourth port for receiving signals in the second direction, the echo cancellation device providing echo cancellation in the signals transmitted in the first and second directions;
   a trunk interface for interfacing with a trunk line having a first port for receiving signals in the first transmission direction from the echo cancellation device, a second port for transmitting signals in the second transmission direction to the echo cancellation device, a third port for receiving and transmitting the received and transmitted signals in the first and second directions to and from a trunk transmission line;
   an echo cancellation controller providing control signals to the echo cancellation device;
   a memory for storing data and control software in communication with the echo cancellation controller; and
   a terminal interface for receiving control signals from an external terminal to the echo cancellation controller and providing status signals from the echo cancellation controller to the external terminal.

2. An integrated digital trunk interface card as in Claim 1 wherein the external terminal is a hand held terminal.

3. An integrated digital trunk interface card as in Claim 1 wherein the external terminal is a personal computer.
4. An integrated digital trunk interface card as in Claim 1 wherein the memory includes nonvolatile memory.

5. An integrated digital trunk interface card as in Claim 1 where in the echo cancellation device provides echo cancellation using a digital signal processor.

6. An integrated digital trunk interface card as in Claim 1 further comprising:
   a processor interface for receiving control signals from the switch and providing control signals to the matrix interface and the trunk interface.

7. An integrated digital trunk interface card as in Claim 5 wherein the processor interface provides control signals to the echo cancellation controller.

8. An integrated digital trunk interface card as in Claim 1 wherein said third port of the trunk interface is in communication with a multiplexer.

9. An integrated digital trunk interface card comprising:
   a matrix interface for interfacing with a switch having a first port for receiving signals in a first transmission direction from the switch, a second port for transmitting signals in a second transmission direction opposite the first transmission direction to the switch, a third port for transmitting the received signals in the first direction and a fourth port for receiving signals in the second direction;

   at least one digital signal processor having software for providing an echo cancellation function
   
   a first digital signal processor port for receiving the signals transmitted in the first direction from the third port of the matrix interface and providing them to the digital signal processor;

   a second digital signal processor port for transmitting the signals transmitted in the second direction to the fourth port of the matrix interface from the digital signal processor;

   a third digital signal processor port for transmitting the received signals in the first direction and a fourth port for receiving signals in the second direction from the digital signal processor;

   a trunk interface for interfacing with a trunk distribution line having a first port for receiving signals in the first transmission direction from the echo
cancellation device, a second port for transmitting signals in the second transmission direction to the echo cancellation device, a third port for receiving and transmitting the received and transmitted signals in the first and second directions to and from a trunk transmission line;

an echo cancellation controller providing control signals to the echo cancellation device;

a memory for storing data and control software in communication with the echo cancellation controller; and

a terminal interface for receiving control signals from an external terminal to the echo cancellation controller and providing status signals from the echo cancellation controller to the external terminal.

10. An integrated digital trunk interface card as in Claim 9 wherein the external terminal is a hand held terminal.

11. An integrated digital trunk interface card as in Claim 9 wherein the external terminal is a personal computer.

12. An integrated digital trunk interface card as in Claim 9 wherein the memory includes nonvolatile memory.

13. An integrated digital trunk interface card as in Claim 9 further comprising:

a processor interface for receiving control signals from the switch and providing control signals to the matrix interface and the trunk interface.

14. An integrated digital trunk interface card as in Claim 13 wherein the processor interface provides control signals to the echo cancellation controller.

15. An integrated digital trunk interface card as in Claim 9 wherein said third port of the trunk interface is in communication with a multiplexer.

16. A method for providing echo cancellation in an integrated digital trunk interface card comprising:

receiving signals in a first transmission direction from a switch at a matrix interface;

transmitting signals in a second transmission direction opposite the first transmission direction to the switch from the matrix interface
receiving the signals transmitted in the first direction from the matrix interface at an echo cancellation device
transmitting the signals transmitted in the second direction to the matrix interface from the echo cancellation device, the echo cancellation device providing echo cancellation in the signals transmitted in the first and second directions;
receiving a signal in the first transmission direction from the echo cancellation device at a trunk interface;
transmitting signals in the second transmission direction to the echo cancellation device from the trunk interface;
receiving and transmitting the received and transmitted signals in the first and second directions to and from a trunk transmission line at the trunk interface;
controlling the echo cancellation device using an echo cancellation device controller;

storing data and control software in a memory in communication with the echo cancellation controller; and

connecting a terminal interface for receiving control signals from an external terminal to the echo cancellation controller and providing status signals from the echo cancellation controller to the external terminal.

17. A method for providing echo cancellation in an integrated digital trunk interface card as in Claim 16 wherein the external terminal is a hand held terminal.

18. A method for providing echo cancellation in an integrated digital trunk interface card as in Claim 16 wherein the external terminal is a personal computer.

19. A method for providing echo cancellation in an integrated digital trunk interface card as in Claim 16 wherein the memory includes nonvolatile memory.

20. A method for providing echo cancellation in an integrated digital trunk interface card as in Claim 16 where in the echo cancellation device provides echo cancellation using a digital signal processor.

21. A method for providing echo cancellation in an integrated digital trunk interface card as in Claim 16 further comprising the step of:
receiving control signals from the switch and providing the control signals to the matrix interface and the trunk interface.
22. A method for providing echo cancellation in an integrated digital trunk interface card as in Claim 21 wherein the processor interface provides control signals to the echo cancellation controller.

23. A method for providing echo cancellation in an integrated digital trunk interface card as in Claim 16 wherein said trunk interface communicates with the trunk transmission line via a multiplexer.
FIG. 1
(PRIOR ART)

FIG. 2
(PRIOR ART)

FIG. 3
(PRIOR ART)

FIG. 4
(PRIOR ART)

SUBSTITUTE SHEET (RULE 26)
INTERNATIONAL SEARCH REPORT

A. CLASSIFICATION OF SUBJECT MATTER
IPC(7) : H04M 1/00, 1/50, 3/42,
US CL : 379/230, 283, 386, 399
According to International Patent Classification (IPC) or to byth national classification and IPC

B. FIELDS SEARCHED
Minimum documentation searched (classification system followed by classification symbols)
U.S. : 379/230, 283, 386, 399

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)
Please See Continuation Sheet

C. DOCUMENTS CONSIDERED TO BE RELEVANT

<table>
<thead>
<tr>
<th>Category</th>
<th>Citation of document, with indication, where appropriate, of the relevant passages</th>
<th>Relevant to claim No.</th>
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<tr>
<td>Y</td>
<td>US 5,479,498 A (BRANDMAN et al) 26 DECEMBER 1995; (Entire patent document).</td>
<td>1, 5, 7, 9, 14, 16, 20, 23,</td>
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<tr>
<td>Y, P</td>
<td>US 5,991, 389 A (RAM et al) 23 NOVEMBER 1999, Figs. 1-11; col. 2, lines 3-67; col. 3 to col. 4; col 6, lines 8-67; col. 7 to col. 25.</td>
<td>1-3, 6, 8, 9-11, 13-15, 16-18, 21-23.</td>
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<td>Y, E</td>
<td>US H11,884 A (PRUETT et al) 03 OCTOBER 2000, Figures 1-7; col. 2, lines 5-64; col. 3, lines 27-67; col. 4 to col. 15; col. 16, lines 1-25.</td>
<td>1-5, 6-9, 12, 14, 16, 19, 20, 21-23.</td>
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<td>Y, E</td>
<td>US 6,124,882 A (VOOIS et al) 26 SEPTEMBER 2000; Figures 1-4; col. 2, lines 8-35; col. 3 to col. 9; col. 12 to col. 14.</td>
<td>4, 8, 10-13, 15, 17-19, 23</td>
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<tr>
<td>A</td>
<td>US 5, 305,312 A (FORNEK et al) 19 APRIL 1994, ALL</td>
<td>1-23</td>
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<td>A</td>
<td>US 5,835,486 A (DAVIS et al) 10 NOVEMBER 1998; ALL</td>
<td>1-23</td>
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Further documents are listed in the continuation of Box C.  See patent family annex.

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Date of mailing of the international search report 26 JAN 2001

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Form PCT/ISA/210 (second sheet) (July 1998)
Continuation of B. FIELDS SEARCHED Item3: US Patents Full-Text Database; JPO Abstracts Database; EPO Abstracts Database; Derwent World Patents Index; IBM Technical Disclosure Bulletins.
Search Terms Used: Digital trunk interface card; Echo cancellation controller; Nonvolatile memory; multiplexer.