Title: METHOD AND APPARATUS FOR TESTING LOOP-BACK COMMUNICATIONS WHILE ELIMINATING THE NEED FOR A LOOP-BACK RELAY.

Abstract: In one embodiment, a test tone(14a) is placed in an outbound path of a full-duplex transmission system. An echo cancellation capability(13) is disabled, enabling an echo signal(16b) of the test tone to pass through the inbound path of the full-duplex transmission system, which echo signal(14b) is analyzed to determine the condition the full-duplex paths. In another embodiment a standard DSP(12) generates DTMF tones which are looped-back and tested by the DSP(12), under control of a CPU(32). The DSP(12) is a standard DSP avoiding the need for any hardware/software modification of the DSP(12) to perform the test mode. The tests are performed in the local level, i.e. at the subscriber’s location, eliminating the need for central office intervention.
[0001] Method and Apparatus for testing loop-back communications while eliminating the need for a loop-back relay.

[0002] BACKGROUND
[0003] The present invention relates to telephone service provided over hybrid fiber/cable broadband connections using Internet Protocol (IP) and more particularly to a simplified method and apparatus for testing the reliability of a residential gateway in one embodiment and for eliminating the need for traditional relay means in another embodiment.
[0004] Residential gateways must be low in cost and yet have high reliability. A key feature in providing reliability utilizes looped-back testing for purposes of remote testing and diagnostics. The traditional looped-back test design requires one relay per local line which adds costs and increases the likelihood of failures.
[0005] Looped-back testing is a standard method for testing full duplex paths within a telephony communication system. In order to perform looped-back testing, the normal path is modified at or near the system boundary to loop outbound messages back into the system on the inbound half of the full duplex path. The looped-back path is normally switched by either hardware or software.
[0006] The looped-back path is normally used only during a test mode. A looped-back test is performed by first enabling the looped-back path where upon a signal is placed on the outbound path. If that signal is detected on the inbound path the test verifies the integrity of the path.
[0007] Figure 1 shows a system employing a conventional testing approach.
[0008] Making reference to Figure 1, a portion 10 of a telephone network comprises a Digital Signal Processor (DSP) 12, which generates a test tone in the form of PCM (Pulse Code Modulation) data at 12a and applies it to circuitry 14 incorporating a CODEC (encoder/ decoder) and a CPLD (Complex Programmable Logic Device - is a logic chip that can be programmed to perform any specific logic function and is similar to a PGS, FPGA or a PLD). The test tone at 12a is converted into an analog signal, appearing at 14a and applied to an SLIC (subscriber line interface circuit) 16 which may alternatively be a hybrid circuit including any SLIC part. The test tone is looped-back to the SLIC 16 through a normally
open looped-back relay 18 which is closed preparatory to receipt of the test tone appearing at 16a through suitable hardware or software (not shown for purposes of simplicity).

[0009] The looped-back test tone, appearing at 18a, is applied through subscriber line interface circuit (SLIC) 16 to circuit 14 which converts the analog signal into digital form, this digital output being applied to the DSP 12 through 14c. DSP 12 receives both the test tone from the looped-back path as well as the echo of the looped-back message, represented by dotted line 14c.

[0010] It is advantageous to determine the integrity of a subscriber line without the need for a looped-back relay which requires hardware and software to operate the looped-back relay and which further complicates the test in the event of faulty operation of the looped-back relay.

[0011] SUMMARY
[0012] It is therefore one object of the present invention to provide novel method and apparatus for determining the integrity of a full duplex path subscriber line while eliminating the need for a looped-back relay and all of the attendant hardware/software required for its appropriate operation.

[0013] Still another object of the present invention is to provide for loop-backed testing of a full-duplex transmission path employing conventional apparatus for generating DTMF tones for test purposes, which apparatus avoids the need for additional software or other modifications.

[0014] Still another object of the present invention is to locally test the integrity of a subscriber's full-duplex transmission path and thereby avoid the need for intervention by a central office, for example.

[0015] The present invention, in one preferred embodiment thereof, utilizes appropriate hardware and software for generating a test tone applied as an outbound message in the full duplex path having a Hybrid Reflection Based Loopback. An echo cancellation circuit, which normally removes a reflection that is typically present in this type of circuit is the means by which the echo is removed. However, upon initiation of a test mode, the echo cancellation capability is disabled and the echo is used as the test signal, providing a simplified and yet effective detection of the return path test tone at the Digital Signal Processor (DSP) 12, thereby increasing reliability while decreasing cost through the
elimination of the looped-back relay and its control means, as well as simplifying the
detection of the return path test tone at the DSP 12.

[0016] An additional embodiment of the present invention, a BTI generates one or
more DTMF tones that are processed through the normal circuitry of the BTI for providing
audio signals to the attached phon(e)s but, rather than applying the signal to a phone, the
signal is looped back and processed by the circuitry that receives the audio signals from the
phone. Software that is conventionally resident in DSP to detect the DTMF tones is used to
analyze the quality of the received signals.

[0017] Although the DSP is an ideal place for checking quality of looped back audio,
it is preferable to use existing DSP software to perform the desired test and thereby avoid the
need for additional hardware/software to perform the test, thus avoiding the need to modify
such existing equipment/software.

[0018] SGCP is a centralized signal protocol requiring that the Call Agent (i.e., the
central call signaling authority) know the call state of each endpoint device in the system. In
existing telephone networks, loopback analysis is performed by a piece of equipment that is
shared across a wide population of equipment and there are no known solutions that provide
local signal analysis. The alternative embodiment makes advantageous use of DTMF
generation/detection software in the generation/analysis of a looped back test signal.

[0019] A central processing unit (CPU) places the hardware into the looped-back
mode and sends a command the DSP to generate DTMF tones which are generated as digital
signals. The digital signals are converted into analog form by the CODEC and transferred to
the SLIC (Subscriber Line Interface Circuit). The signal is looped back through the SLIC,
converted to digital form by the CODEC and processed by the DSP, which processes the
test tones in the normal manner, reporting the results to the CPU, which then determines the
integrity of the signal path. This technique utilizes the DTMF tones and loops back the
signal through the SLIC, eliminating the need for reconfiguration or modification of the DSP
and/or its attendant hardware/software.

[0020] BRIEF DESCRIPTION OF THE DRAWING(S)

[0021] The above as well as other objects of the present invention will become
apparent when reading the accompanying description and drawings, in which:
[0022] Figure 1 is a simplified block diagram useful in explaining the conventional technique for testing a subscriber line through the use of a looped-back relay.

[0023] Figure 2 is a block diagram useful in describing one preferred embodiment of the present invention.

[0024] Figure 2a is a simplified block diagram shown of an echo cancelling function.

[0025] Figure 3 is a block diagram useful in describing another preferred embodiment of the present invention.

[0026] DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0027] Making reference to Figure 2, wherein like elements employed in Figures 1 and 2 are designated by like numerals, DSP 12 generates a digital test tone at 12a and applies it to CODEC circuit 14. The test tone, converted to analog form, is applied through 14a to the SLIC 16. The SLIC is the interface between the 2-wire line within the house and the 4-wire line output of the Codec 14. There is typically an impedance mismatch between the 2-wire and the 4-wire segments of the line. Any signal crossing the interface will also be reflected backwards. When delayed by a significant time, it is heard as an echo. The test tone, in addition to being transferred to local telephone 19 through line 16a, causes an echo to appear in the return line resulting from the hybrid reflection based loopback. The loopback test can be performed on a line with no attached phones and it is not necessary that a local phone be provided to perform the test. The echo, appearing a 16b, is applied to circuit 14 where it is converted into digital form and applied, at 14b, to Digital Signal Processor (DSP) 12. The echo cancellation function is performed by the DSP. There is an API interface to control echo cancellation function. The CPU uses the API to turn off the echo cancellation. The echo signal, however, which is not cancelled, is utilized as a test signal and its presence is indicative of a satisfactory operating full duplex path.

[0028] Fig. 2a shows a functional diagram of echo canceller 13. The echo canceller 13, which is conventional, forms part of the DSP 12 (see Fig. 2) and applies the source of the echo to an echo estimator function. The echo estimator function 13a generates an estimate of the echo for the echo subtracter. The echo subtracter 13b removes the echo from the inbound signal by subtracting the echo estimate. The output of the echo subtracter is used to fine tune the echo estimator 13a during periods where there is no local signal except for echo. During all loopback testing, the echo cancellation function must be turned off or
disabled because, the echo cancellation function will treat the loopback tones as echo and subtract it out. The CPU 32 uses the API to turn off the echo canceller, enabling the echo to be employed as the test signal. The receipt and detection of an echo signal assures the integrity of the residential gateway.

[0029] Figure 3 shows still another embodiment 30 of the present invention in which CPU 32 generates a command at 32a causing the DSP 12 to generate DTMF tones. Just prior to this command, CPU 32 provides a control at 32a to place the hardware in the looped-back mode, providing a loopback circuit as shown as 34, using a relay-based loopback of the type shown, for example, in Fig. 1. The loopback test is initiated by SNMP. DSP 12, after receiving the command signal, generates DTMF tones and applies these tones at 12a to CODEC 14, which digital tones which are converted into analog form and sent to the SLIC 16. The DTMF tone generated by the DSP is, in one preferred embodiment, composed of a 941 Hz tone and a 1209 Hz tone, both tones being provided at a power level of -14dBm for a period preferably of the order of 100 milliseconds. The echo based test in the embodiment of Fig. 2 may use similar tones at a different volume level depending on the strength of the echo. It is possible that a customer might press a key on the telephone keyboard that matches the DTMF tones used for the test, and that tone could reach the SLIC, resulting in the tone being detected even though the SLIC is faulty. However, this is highly unlikely. In order to significantly reduce the likelihood of operation of a key by the customer which produces the test tone, a multiple tones sequence may be employed. The DTMF tones looped-back through SLIC 16, are applied at 16a to CODEC 14 where they are converted into digital format and applied to DSP 12.

[0030] DSP 12 detects and processes DTMF tones in the conventional manner (requiring no additional hardware/software to accomplish this), reporting the results to the CPU 32. This technique permits utilization of the conventional software capabilities of the DSP as the means for testing the subscriber circuit, further avoiding the need for providing the DSP with any additional hardware/software, thereby avoiding the need to convert or modify conventional equipment as well as equipment already in place in the field in order to perform local testing of the full-duplex transmission path.
[0031] It should be noted that the above tests are performed when the local phones are on hook. If any phone goes off hook the test is stopped.

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CLAIMS

What is claimed is:

1. A method for testing a full-duplex transmission system having outbound and inbound paths, comprising:
   a) generating a test signal;
   b) coupling a test tone at a subscriber's location through the outbound path;
   c) detecting for presence of an echo of the test tone in the inbound path; and
   d) determining a condition of the full-duplex transmission system based on the detected echo signal.

2. The method of claim 1 further comprising initially generating a request for a test tone, and
   e) further comprising generating a test tone responsive to the request for the test signal.

3. The method of claim 1 wherein step (a) further comprises generating a test tone in digital format; and
   converting the test tone into analog form for placement on the outbound path.

4. The method of claim 1 further comprising:
   a) generating a status signal to indicate a condition in the full duplex transmission path responsive to the condition determined at step (d).

5. The method of claim 4 further comprising transmitting a signal representing a condition of the full duplex transmission path to a remote location.

6. The method of claim 2 further comprising generating a pseudo echo signal to be combined with a signal in the inbound path for cancelling an echo signal; and
   disabling generation of the pseudo echo signal responsive to a request for a test tone, whereby the test tone signal employed for detection is an echo signal.
7. A method for testing a condition of a full duplex transmission system having inbound and outbound paths and having an echo cancelling capability; comprising:
   a) generating a request for a test tone;
   b) generating a test tone responsive to said request;
   c) placing the test tone on the outbound path;
   d) disabling echo cancellation; and
   e) analyzing the echo signal to determine status of the transmission system.

8. A method for testing reliability of a subscriber's line having a processor capable of generating DTMF tones, comprising:
   a) establishing a loopback path between an output end of an outbound path and an input of an inbound path;
   b) instructing the processor to generate DTMF tones;
   c) applying the tones to the outbound path whereupon the DTMF tones enter an input of the inbound path through said loopback path;
   d) causing the processor to analyze the looped-back signal entering the inbound path and appearing an output thereof; and
   e) determining a condition of the subscriber line based upon the analysis performed in step (d).

9. The method of claim 8 wherein step (b) further comprises generating digital DTMF tones; and
   converting the digital DTMF tones into analog form for placement on the outbound path; and
   step (c) further comprises converting the looped-back signal into digital form for analysis by the processor.

10. In a full-duplex transmission path, a processor generating DTMF tones in digital form;
    a converter for converting digital DTMF tones into analog form;
    an SLIC including an outbound and an inbound path;
a controller for establishing a looped-back path between an output of the SLIC outbound path and an input of the SLIC inbound path and enabling the processor to generate DTMF tones for application to an input of the outbound path; and

said processor analyzing a loopback signal passing through said inbound path to determine integrity of the transmission path.

11. The full-duplex transmission path of claim 10 further comprising a convertor for converting looped-back analog signals in the SLIC inbound path into digital form for analysis by the processor.

12. The full duplex transmission path of claim 10 wherein the processor analyzes the looped-back DTMF signals received from the SLIC inbound path.

13. The full duplex transmission path of claim 10 wherein said processor is a digital signal processor.

14. In a telephony network of the IP or ATM type, a processor generating a test tone;

an SLIC having hybrid linked outbound and inbound paths;

said outbound path receiving the generated test tone;

said test tone in the outbound path causing an echo signal to be developed in the SLIC inbound path;

said inbound path being coupled to said processor;

a circuit for cancelling an echo received in the inbound path;

said processor disabling the echo cancelling circuit when generating the test tone, enabling the processor to analyze the echo signal when the output end of the outbound path and the input end of the inbound path are in an open-loop condition.

15. The telephony network of claim 14 wherein the processor generates digital DTMF tones;

a convertor for converting digital DTMF tones into analog form for transmission through the SLIC outbound path; and
a convertor for converting the echo signal at an output end of the inbound path into digital form for analysis by said processor.

16. The telephony network of claim 15 wherein said processor is a digital signal processor (DSP).

17. The telephony network of claim 15 wherein the processor enables the echo cancelling capability upon completion of analysis of the looped-back signal.

18. The telephony network of claim 14 wherein the processor disables the echo cancelling circuit at least prior to receipt of the echo signal in said inbound path.

19. A method for locally testing a subscriber's full-duplex transmission in an IP network having outbound and inbound paths, comprising:
generating a test tone;
coupling the test tone to the subscriber's location through a forward path of the full duplex transmission;
detecting for presence of an echo of the test tone in the return path of the full duplex transmission; and
determining a condition of the full-duplex transmission system based on the detected echo signal.

20. The method of claim 19 further comprising preventing generation of a test tone when the subscriber's telephone is off-hook.

21. The method of claim 19 wherein said network includes an echo canceller, said method comprising deactivating the echo canceller to enable detection of the echo signal; and
converting the test tone into analog form for placement on the outbound path.
INTERNATIONAL SEARCH REPORT

A. CLASSIFICATION OF SUBJECT MATTER
IPC(7) : HO4M 1/24
US CL. : 379/3
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. : 379/3, 22.01, 22.02, 406.04, 406.06; 370/249, 286, 287

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

<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 5,881,129 A (CHEN et al) 09 March 1999 (09.03.1999), abstract, figures 1-4, columns 1-20.</td>
<td>1-21</td>
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☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:
  "Y" 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
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