

(19) World Intellectual Property Organization
International Bureau



(43) International Publication Date
15 August 2002 (15.08.2002)

PCT

(10) International Publication Number
WO 02/063858 A1

(51) International Patent Classification: H04M 1/24

(21) International Application Number: PCT/US02/03820

(22) International Filing Date: 8 February 2002 (08.02.2002)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
09/779,092 8 February 2001 (08.02.2001) US

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(81) Designated States (*national*): AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NO, NZ, OM, PH, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TN, TR, TT, TZ, UA, UG, UZ, VN, YU, ZA, ZM, ZW.

(84) Designated States (*regional*): ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

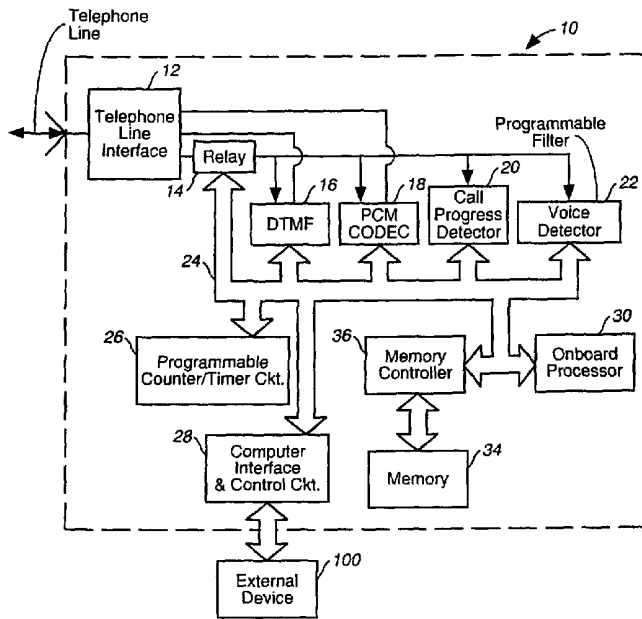
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Published:
— with international search report

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For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

(54) Title: A METHOD AND APPARATUS FOR ESTIMATING QUALITY IN A TELEPHONIC VOICE CONNECTION



(57) Abstract: A device (10) is disclosed that uses an continuous analytical function (514) representing mapping data relating object voice connection measurements to likely user perception of the quality of a voice connection. The device (10) is compact and inexpensive. It can be implemented on a single integrated circuit (18), or on a single printed circuit board. CPU (30) processing time is significantly reduced. The device (10) obtains a real-time estimate of likely user perception of a given connection in terms of a user perception rating system (514). The device (10) is reprogrammable, enabling it to be updated as more accurate mapping data is obtained.

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A METHOD AND APPARATUS FOR ESTIMATING QUALITY IN A
TELEPHONIC VOICE CONNECTION

BACKGROUND OF THE INVENTION

15 1. Field of the Invention

The present invention relates generally to telecommunications, and particularly to a method and system for evaluating the quality of voice signals.

2. Technical Background

20 Telephone connections have always been subject to impairments in the form of noise, attenuation, distortion, cross-talk and echo. Such impairments are particularly common to analog portions of the network, such as subscriber loops and frequency domain multiplexing equipment. Digital transmission alleviates any of these problems but also introduces quantization noise and distortions due to bit errors in the digital
25 signal. However, even with perfect digital transmission applied to long haul transmissions, a typical telephone connection includes many analog components, wherein impairments can occur.

A poor connection or malfunctioning piece of equipment can produce conditions that a telephone customer will find objectionable or intolerable. When there
30 is a high incidence of poor connections, customers may complain to the service provider or to a regulatory authority, or simply change long distance carriers. Thus,

5 perceived quality of telephone connections is a major factor affecting the reputation and marketability of long distance telephone services.

To guard against poor quality, service providers have developed methods to obtain objective quality measurements upon a line, piece of equipment, or an end-to-end telephone connection. These measurements can help the service provider detect
10 and gauge impairments, pinpoint weak elements, and correct deficiencies that degrade user perception of quality. The effects of extreme fault conditions on user perception of quality is clear. There are easily discernable thresholds for "no effect" and "substantial degradation" conditions. Unfortunately, for intermediate objective quality measurements, there is no clear division between values representing acceptable and
15 unacceptable voice connection quality.

In one approach that was discussed in the parent application, mappings were created between objective measurements and user perceived quality ratings. A set of objective characteristics for a telephonic connection were obtained. Test signals were produced by varying each element in the set of objective characteristics, and by varying
20 various combinations of the objective characteristics. Each test signal was subjectively rated by a large group of evaluators using a "no impairment," "some impairment," or "much impairment" rating system. These data mappings were synthesized by constructing a look-up table. The quality of a telephonic connection can be assessed using this mapping system. When a set of objective measurements for a telephonic
25 connection are obtained, the look-up tables can be used to provide a network analyst with an estimate of the perceived quality level for the connection. This mapping system is a powerful tool for analyzing reported impairments, or for testing new network plant or equipment before deployment.

However, there are several shortcomings associated with the approaches
30 described above. Although look-up tables can be used to store the mapping data, it would be difficult to use them to provide a device capable of real time processing to produce measurements. The use of a look-up table that contains all of the mappings would substantially increase memory requirements and necessitate a prohibitive amount of processing. The CPU in such a device would be required to perform a large number
35 of operations. Because the contents of the look-up table are discrete mappings, the accuracy of a real time estimate may be poor.

5 Thus, what is needed is a device that uses an analytical representation of the mapping tables. In other words, the mapping data in the data tables would be modeled as a continuous analytical transform. This would significantly reduce costs, and the size of a resultant voice quality estimation device. By using a continuous mathematical function, CPU processing time would be significantly reduced, allowing the device to
10 obtain a real-time estimate of likely user perception of a given connection in terms of the user perception rating system described above. Finally, a reprogrammable device is needed that can be updated as more accurate mapping data is obtained.

15

SUMMARY OF THE INVENTION

The present invention includes a device that uses an continuous analytical function representing the above described mapping tables. The device is compact and inexpensive. It can be implemented on a single integrated circuit, or on a single printed circuit board. CPU processing time is significantly reduced. The device obtains a real-
20 time estimate of likely user perception of a given connection in terms of the user perception rating system described above. Finally, the device and system processes are readily reprogrammable by specification of configuration parameters, enabling it to be updated as more accurate mapping data is obtained.

One aspect of the present invention is a device for evaluating quality in a
25 telephonic voice connection in a telecommunications network. The device includes a measurement circuit operative to measure at least one characteristic of the telephonic voice connection. A processor is coupled to the measurement circuit, the processor being operative to calculate a solution to at least one empirically derived mathematical function by using the at least one measured characteristic as an independent variable in
30 the at least one empirically derived mathematical function, whereby the solution is an estimate of likely user perception of the quality of the telephonic voice connection.

In another aspect, the present invention includes a method for evaluating quality in a telephonic voice connection in a telecommunications network. The method includes establishing a telephonic voice connection. At least one characteristic of the

5 telephonic voice connection is measured. A solution to at least one empirically derived mathematical function is calculated by using the at least one measured characteristic as an independent variable in the at least one empirically derived mathematical function, whereby the solution is an estimate of likely user perception of the quality of the telephonic voice connection.

10 In another aspect, the present invention includes a programmable device for evaluating quality in a telephonic voice connection in a telecommunications network. The device includes a memory operative to store at least one empirically derived mathematical function having at least one independent variable. A processor is coupled to the memory, the processor being operative to calculate a solution to the at least one
15 empirically derived mathematical function by using at least one measured characteristic as the independent variable, whereby the solution is an estimate of likely user perception of the quality of the telephonic voice connection. An interface control circuit is coupled to the memory, the interface control circuit being adapted to receive a revised at least one empirically derived mathematical function from an external device,
20 and store the revised at least one empirically derived mathematical function in the memory.

In another aspect, the present invention includes a method for fabricating a device for evaluating quality in a telephonic voice connection in a telecommunications network. The method includes empirically acquiring user perception data by having at
25 least one test subject listen to a plurality of test messages, and rate the quality of each test message in accordance with at least one user perceived impairment characteristic. The user perception data is modeled as at least one mathematical function, the at least one mathematical function being graphically represented by a two dimensional curve having a shape, the shape of the curve being determined by a set of constants employed
30 in the at least one mathematical function. Values are chosen for the set of constants to thereby fit the two-dimensional curve to the user perception data to thereby generate at least one empirically derived mathematical function. The at least one empirically derived mathematical function is converted into a set of computer executable instructions. The device is programmed with the set of computer executable
35 instructions.

In another aspect, the present invention includes a computer readable medium having computer executable instructions for performing a method. The method

5 includes establishing a telephonic voice connection. At least one characteristic of the telephonic voice connection is measured. A solution is calculated for the at least one empirically derived mathematical function by using at least one measured characteristic as an independent variable of the at least one empirically derived mathematical function.

10 Additional features and advantages of the invention will be set forth in the detailed description which follows, and in part will be readily apparent to those skilled in the art from that description or recognized by practicing the invention as described herein, including the detailed description which follows, the claims, as well as the appended drawings.

15 It is to be understood that both the foregoing general description and the following detailed description are merely exemplary of the invention, and are intended to provide an overview or framework for understanding the nature and character of the invention as it is claimed. The accompanying drawings are included to provide a further understanding of the invention, and are incorporated in and constitute a part of
20 this specification. The drawings illustrate various embodiments of the invention, and together with the description serve to explain the principles and operation of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

25 Figure 1 is a diagrammatic depiction of the voice quality estimation device in accordance with the present invention;

Figure 2 is an example of the voice quality estimation device being used in a Telephonic Quality Measurement System (TQMS);

30 Figure 3 is an example of the voice quality estimation device being used as OEM equipment at a customer's premises;

Figure 4 is an example of the voice quality estimation device being used in a central office environment;

Figure 5 is a flow chart showing a method for making the voice quality estimation device of the present invention; and

5 Figure 6 is a plot of the empirically derived mathematical functions.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Reference will now be made in detail to the present preferred embodiments of
10 the invention, examples of which are illustrated in the accompanying drawings.
Wherever possible, the same reference numbers will be used throughout the drawings
to refer to the same or like parts. An exemplary embodiment of the device for
estimating telephonic voice connection impairments of the present invention is shown
in Figure 1, and is designated generally throughout by reference numeral 10.
15 In accordance with the invention, the present invention for a device for estimating user
perception of the quality of a telephonic voice connection includes a processor coupled
to a measurement circuit. The processor is operative to calculate a solution to at least
one empirically derived mathematical function by using at least one measured
characteristic as an independent variable in the at least one empirically derived
20 mathematical function. The solution is an estimate of likely user perception of the
quality of the telephonic voice connection. The at least one empirically derived
mathematical function is an analytical representation of the above described mapping
data. As a result, the device is compact and inexpensive. It can be implemented on a
single integrated circuit, or as a single printed circuit board. CPU processing time is
25 significantly reduced. The device obtains a real-time estimate of likely user perception
of a given connection in terms of the user perception rating system described above.
Finally, the device is reprogrammable by specifying new parameters, enabling it to be
updated as more accurate mapping data is obtained. These parameters are the
coefficients that define the mathematical function. In another embodiment, the
30 coefficients are changed using on-board processing by including a processing routine
that operates on another set of parameters in volatile memory to produce the
coefficients.

As embodied herein, and depicted in Figure 1, a diagrammatic depiction of
device 10 for estimating user perception of the quality of a telephonic voice connection
35 in accordance with the present invention is disclosed. Device 10 includes telephone
line interface 12 which connects device 10 to a telephone line in the network. In one
embodiment, interface 12 is adapted to interface with network by means of an RJ-11

5 telephone jack. Interface 12 is coupled to relay 14. Relay 14 is a conventional relay that distributes signals received from interface 12 to DTMF 16, PCM codec 18, call progress detector 20, and voice detector 22. Each of the above listed components are internally coupled by system bus 24. Device 10 also may include programmable counter/timer circuit 26. System bus 24 is also coupled to computer interface circuit
10 28, processor 30, and memory controller 36. Memory controller 36 is coupled to memory 34, which is used to store computer executable instructions.

Telephone line interface 12 may be of any suitable type, but by way of example, interface 12 includes an integrated circuit such as a Motorola MC3401OP coupled to isolation transformers to prevent any grounding problems. Signals from the network
15 are translated by interface 12 into signals having a correct format and amplitude. Interface 12 may also include a buffer amplifier and an adjustable potentiometer to provide optimal signal levels.

DTMF (dual tone multi-frequency) transceiver 16 is operative to generate and detect audible tones associated with a telephone network. DTMF 16 is also adapted to
20 generate DTMF dialing tones to initiate a call through the telephone line coupled to interface 12. DTMF 16 detects DTMF tones received from the telephone line via interface 12.

PCM codec transceiver 18 uses a standard digitization scheme to band limit voice frequencies to the 300 - 3300Hz frequency band. Codec 18 performs an A/D
25 conversion of an analog voice message using a μ -law companding scheme. When sampling the analog waveform, larger amplitudes are compressed relative to the smaller amplitudes, providing an equivalent 12-bit accuracy within an 8-bit digital word. The 8-bit words generated by codec 18 can be stored in a RAM portion of memory 34 or in a memory resident in processor 30. In one embodiment, codec 18 includes a
30 semiconductor IC manufactured by SGS Thompson or by the National Semiconductor Company having the product number ETC5056, or equivalent.

Call Progress Detector 20 is operative to continuously monitor call progress information being fed to device 10. Detector 20 is tuned to a particular frequency band (e.g., 300-630Hz) where most of the fundamental energies of the call progress

5 information reside. The duration of incoming signals such as dial tone, ring back, busy, or fast busy are recorded. Detector 20 monitors the frequency band of interest and looks for the duration of on and off times, and classifies the examined signal as one of the above noted tones.

10 Voice detect circuit 22 is fabricated using standard operation amplifier circuits to detect signals in the band between 750Hz and 4KHz. When a voice waveform is detected, the output within this frequency band is amplified and translated into a digital signal by codec 18. Voice detection may also trigger a response such that a test message is retrieved from memory 34 and converted into an analog signal by codec 18 for transmission over the telephone connection.

15 In yet another embodiment, the output of a detector showing power/no power on a number of different filters to accomplish the functions described for call progress controller and voice detection circuit 22. Reference is made to U.S. Patent No. 5,241,584, which is incorporated herein by reference as though fully set forth in its entirety, for a more detailed explanation of this component.

20 Programmable counter/timer 26 may be of any suitable type providing timing signals of various frequencies as required by the components in device 10. A timing crystal is coupled to programmable counter/timer 26. All of the frequencies generated by counter/timer 26 are synchronous with the base frequency generated by the timing crystal. Programmable counter/timer 26 generates the system clock signal provided by bus 24 and used by processor 30.

25 Memory 34 may be of any suitable type, but by way of example includes a read/write random access memory (RAM) used in data processing and data I/O, and an erasable read only memory for storing device 10 programming instructions used by processor 30 and co-processor 32. The memory used to store the programming instructions can be implemented using a DRAM, PROM, EEPROM, hard drive, compact disk, or any computer readable medium. Memory controller 36 controls the requests from the various components in device 10 on bus 24.

30 Computer interface 28 is adapted to communicate with external device 100. The programming instructions stored in memory 34 can be completely replaced or partially replaced with new instructions down loaded from external device 100. As more research is performed, the empirical data used to formulate the instructions stored in memory 34 may become outdated. If so, device 10 can be returned to a central

5 location and reprogrammed with instructions representing the latest empirical data. In
another embodiment, the device can be reprogrammed by simply entering new data via
a keyboard (not shown). In this embodiment, the empirical mapping data takes the
form of constants used to shape a cumulative probability distribution function. In order
to reprogram device 10, an operator in the field need only input a new set of constants.
10 The nature of the cumulative probability distribution function will be discussed in more
detail below.

In one embodiment processor 30 is implemented using an 8-bit semiconductor
chip such as the 80486 IC manufactured by Intel. This is more than adequate since the
calculations performed by processor 30 do not require much processing power. Thus,
15 the present invention can be implemented using the lowest cost components on the
market. However, one of ordinary skill in the art will recognize that 16-bit, or even 32-
bit machines can be used to implement processor 30, depending on speed, cost and
other design considerations. Those of ordinary skill in the art will also recognize that
processor 30 can be implemented using an application specific integrated circuit
20 (ASIC). In another embodiment processor 30 is implemented using a 4-bit processor.
In this alternative embodiment, processor 30 merely controls and effects the recording
of the received signal so less processing power is required. The recording is
transmitted to external host processor 100. One benefit of this approach is that the data
interpretation software can be easily changed. In the first embodiment discussed above,
25 the firmware resident in memory 34 has to be changed, unless the processing routine
for recalculating the coefficients is included.

As embodied herein and depicted in Figure 2, an example of device 10 being
used in Telephone Quality Measurement System (TQMS) environment 200 is
disclosed. In this embodiment, device 10 is implemented as a circuit board connected
30 to motherboard 204 within TQMS personal computer platform 202. Device 10 is
coupled to network 206 enabling recordings of signals received over the network to be
passed to TQMS platform 204. Network 206 may be a circuit switched network, a
packet switched network, or a hybrid that includes both. Network 206 is coupled to
customer 208. In this example, customer 208 may be a customer who has filed a

5 complaint, or a new customer. Referring back to Figure 1, processor 30 directs interface 12 and DTMF 16 to establish a voice connection with customer 208. Subsequently, a recorded message stored in memory 34 is converted into an analog signal by codec 18. The message directs the customer to respond in various ways to message prompts to thereby obtain a voice sample and a quiet channel sample. From
10 the voice sample and the quiet channel sample, device 10 can obtain measurements of objective characteristics such as C-message noise, magnitude of average power of speech, magnitude of average power of a quiet channel, echo path delay, echo path loss, a speech distortion indicator, and a dropped frame rate in a packet switched network. Processor 30 uses the objective measurement as the independent variable of the
15 empirically derived mathematical functions stored in memory 34 to calculate solutions to the empirically derived mathematical functions. Device 10 provides TQMS 202 with likely user perception data including an estimate of the percentage of users that would deem the voice connection to have no impairment, some impairment, and much impairment. In one embodiment, device 10 performs all of the processing, and merely
20 transmits the results to external device 100. This embodiment is enabled by the processing efficiencies realized by the method of the present invention. The look-up process is reduced to retrieving the few parameters used in evaluating the mathematical functions. The current model is changed by writing replacement parameters into memory 34. In an alternate embodiment, PC motherboard 204, and the resident
25 memory thereon, are the destination of the recordings captured by device 10. Thus, in the alternate embodiment, PC 204 represents external device 100 depicted in Figure 1.

As embodied herein and depicted in Figure 3, an example of device 10 being used as an OEM equipment in customer premises environment 300 is disclosed. In this example OEM device 10 is plugged into RJ-11 jack at the customer's premises to
30 provide a physical connection to network 302. Network 302 is connected to a plurality of network customers LOC#1, LOC#2, through LOC#N. In this scenario, the customer may have acceptable service when calling some telephone numbers, and unacceptable service when calling others. OEM device 10 can be programmed to call these telephone numbers, or any suite of numbers for that matter. OEM device 10 operates as
35 described above to obtain the user perception data for each connection, allowing analysts to pin-point that portion of network 302 that is malfunctioning.

5 As embodied herein and depicted in Figure 4, an example of device 10 being
used in central office environment 400 is disclosed. In this example, device 10 is
implemented as single IC (a microprocessor or an ASIC) that is disposed on a circuit
board within central office switch 402. Alternatively, device 10 is implemented as a
10 printed circuit board coupled to switch 402. Switch 402 is coupled to the central office
district network 404, and/or a long haul network 406. This application is a powerful
one because it allows central office switch 402 to obtain an estimate of user perception
of the quality of any voice connection made by switch 402. Device 10 provides switch
402 with the percentage of users that would likely characterize the connection as having
15 no impairment, some impairment, and much impairment with respect to at least one
impairment measured by an objective assignment of values. The sum of the
percentages must equal 100%. For example, a connection under test may be
characterized as: 10% of users likely to find no impairment; 85% of users likely to find
some impairment; and 5% of users likely to find much impairment. Device 10 can be
used to test new plant, or an existing portion of a network.

20 As embodied herein and depicted in Figure 5, a flow chart showing a method
for making a voice quality estimation device 10 is disclosed. Reference is made to
parent U.S. Patent Application No. 09/220, 733 which is incorporated herein by
reference as though fully set forth in its entirety, for a more detailed explanation of
steps 502 – 512.

25 In step 502, user perceived characteristics are selected to broadly characterize
the variety of voice impairments that might be manifested in a telephonic voice
connection. Test subjects are instructed to rate a voice connection as having “no
impairment” if the test subject cannot detect the presence of an impairment. A test
subject is instructed to rate a voice connection as having “much impairment” if an
30 impairment is present and noticeable. A test subject is instructed to rate a voice
connection as having “some impairment” if the degree of impairment is somewhere in
between.

 The subjective user perceived characteristics must be tied to objective
characteristics. In step 504, objective quality characteristics of a voice connection are

5 selected. Objective quality characteristics are voice connection characteristics that can be measured. They include: C-message noise, magnitude of average power of speech, magnitude of average power of a quiet channel, echo path delay, echo path loss, a speech distortion indicator, and a dropped frame rate in a packet switched network.

10 In step 506, a plurality of test messages are generated. Each test message has a different combination of C-message noise, average power of speech, average power of quiet channel, echo path delay, echo path loss, distortion, or dropped frames(in a packet switched environment).

15 In step 508, subjective test subjects are used to evaluate the each message. Each evaluator will listen to the series of test messages, which may be received in calls placed over a network in use, and rate each one in accordance with the "none," "some," or "much" standard. In step 510, the user perception data generated in step 508 is collected, and quantified in step 512 to thereby produce data tables summarizing the percentages of user reports of none, some, and much impairment for each interval of the objectively measured voice connection characteristics.

20 In step 514, the mapping data is modeled as a continuous analytical transform. P_m is defined as the likely percentage of users that would characterize a given voice connection as having much impairment. P_n is defined as the likely percentage of users that would characterize a given voice connection as having no impairment. P_s is defined as the likely percentage of users that would characterize a given voice connection as
25 having some impairment.

P_m is modeled as a smooth cumulative probability distribution function which takes on the value zero (0) for the best measured results and asymptotically increases to one (1) as the measured results become worse. The smooth cumulative probability distribution function takes the form of an "s" curve which is expressed by the
30 mathematical function:

$$P_m = 1 - \exp[-a(x-c)^b] \quad (1)$$

P_n is modeled as a smooth cumulative probability distribution function which takes on the value one (1) for the best measured results and asymptotically decreases to
35 zero (0) as the measured results become worse. The smooth cumulative probability distribution function takes the form of an inverse "s" curve which is expressed by the mathematical function:

5
$$P_n = \exp[-d(x-c)^e]. \quad (2)$$

P_s is a Normal distribution that achieves its maximum value somewhere between the extreme points set for the curves describing P_n and P_m . As a result of equations (1) and (2),

10
$$P_s = 1 - (P_n + P_m), \quad (3)$$

$$P_s = \exp[-a(x-c)^b] - \exp[-d(x-c)^e]. \quad (4)$$

Figure 6 is a plot of the curves for equations P_n , P_m , and P_s . Reference 602 is a plot of equation (1). Reference 604 is a plot of equation (2). Reference number 606 is a plot of equation (3).

Referring to step 516 in Figure 5, equations (1), (2), and (4) are fit to the empirical data in the data tables by using analytical and heuristic data fitting routines. These routines produce the desired continuous representation of the transition from $P_n =$
 20 1 to $P_m = 1$ as the objective measured characteristic changes from very good to very bad. Data fitting routines such as those used in step 516 are well known to those of ordinary skill in the art. Essentially, a , b , and c in equations (1) and (4), and c , d , and e in equations (2) and (4), are constants that control the shape of curves 602, 604, and 606, in Figure 6. These constants are programmed into device before use. The data
 25 fitting routines discussed above choose constants a , b , d , and e to thereby obtain empirically derived mathematical functions for P_n , P_m , and P_s . The constant "c" is a value for the objective measurement for which one would expect that there should be no complaint of impairment. For example, if the objective measure is C-message noise, setting $x = c = 5\text{dBmnc}$, would result in a percentage of users deeming the connection to
 30 have no impairment at close to 100%. Thus, x is the independent variable. The measured objective characteristic is plugged into equations (1), (2), and (4) to calculate the estimates of user percentages for the none, some, and much categories.

5 In another embodiment, step 516 is implemented on-chip by including a processing routine. The processing routine uses empirical data written into volatile memory to calculate coefficients a-e.

 In steps 518 and 520, the empirically derived mathematical functions for P_n , P_m , and P_s are converted into computer executable instructions and loaded into the device.

10 The term "computer executable instructions" should be construed to include programming instructions for a microprocessor or some other computing device, a programmable logic array, or configuring the circuitry of an ASIC. The step of loading should be construed to cover writing instructions to any memory device, such as a
15 DRAM, ROM, PROM, EEPROM, a hard drive, or some other information bearing device. It should also be construed to cover configuring the gate arrays or other structures in a programmable logic device.

 One of ordinary skill in the art will recognize that steps 502 to 512 are preliminary steps. The compactly defined function obtained in step 514 represents the data obtained in steps 502 to 512.

20 It will be apparent to those skilled in the art that various modifications and variations can be made to the present invention without departing from the spirit and scope of the invention. Thus, it is intended that the present invention cover the modifications and variations of this invention provided they come within the scope of the appended claims and their equivalents.

What is claimed is:

1. A device for evaluating quality in a telephonic voice connection in a telecommunications network, the device comprising:
 - a measurement circuit operative to measure at least one characteristic of the telephonic voice connection; and
 - a processor coupled to the measurement circuit, the processor being operative to calculate a solution to at least one empirically derived mathematical function by using the at least one measured characteristic as an independent variable in the at least one empirically derived mathematical function, whereby the solution is an estimate of likely user perception of the quality of the telephonic voice connection.
2. The device of claim 1, wherein the at least one empirically derived mathematical function is a cumulative probability distribution function.
3. The device of claim 1, wherein the at least one empirically derived mathematical function includes a first function (P_N) representing a proportion of users that will perceive the telephonic voice connection as having no impairment, a second function (P_S) representing a proportion of users that will perceive the telephonic voice connection as having some impairment, and a third function (P_M) representing a proportion of users that will perceive the telephonic voice connection as having much impairment, where $P_N + P_S + P_M = 1$.
4. The device of claim 3, wherein the first function includes the equation

$$P_N = \exp [-a(x-c)^b].$$
5. The device of claim 4, wherein a and b are empirically derived constants, and c represents a noise level that substantially all users would perceive as being unacceptable.
6. The device of claim 3, wherein the third function includes the equation

$$P_M = 1 - \exp [-d(x-c)^e].$$

7. The device of claim 6, wherein d and e are empirically derived constants, and c represents a noise level that substantially all users would perceive as being unacceptable.
8. The device of claim 3, wherein the second function is characterized by the equation
- $$P_s = \exp[-a(x-c)^b] - \exp[-d(x-c)^e].$$
9. The device of claim 8, wherein a , b , d and e are empirically derived constants, and c represents a noise level that substantially all users would perceive as being unacceptable.
10. The device of claim 1, wherein the at least one characteristic is selected from the group consisting of C-message noise, magnitude of average power of speech, magnitude of average power of a quiet channel, echo path delay, echo path loss, a speech distortion indicator, and a dropped frame rate in a packet switched network.
11. The device of claim 1, wherein the network is a packet switched network
12. The device of claim 1, wherein the network is a circuit switched network.
13. The device of claim 1, further comprising a network interface coupled to the measurement circuit, the network interface being operative to establish the telephonic voice connection between the device and the network.
14. The device of claim 1, further comprising:
- a memory operative to store at least one empirically derived mathematical function having at least one independent variable; and
 - an interface control circuit coupled to the memory, the interface control circuit being adapted to receive a revised at least one empirically derived mathematical function from an external device, and store the revised at least one empirically derived mathematical function in the memory.

15. A circuit switched telecommunications network comprising the device of claim 1.
16. A packet switched telecommunications network comprising the device of claim 1.
17. A telecommunications switching device comprising the device of claim 1.
18. A method for evaluating quality in a telephonic voice connection in a telecommunications network, the method comprising:
- establishing a telephonic voice connection;
 - measuring at least one characteristic of the telephonic voice connection; and
 - calculating a solution to at least one empirically derived mathematical function by using the at least one measured characteristic as an independent variable in the at least one empirically derived mathematical function, whereby the solution is an estimate of likely user perception of the quality of the telephonic voice connection.
19. The method of claim 18, wherein the at least one empirically derived mathematical function further comprises:
- a first function (P_N) representing a proportion of users that will perceive the telephonic voice connection as having no impairment;
 - a second function (P_S) representing a proportion of users that will perceive the telephonic voice connection as having some impairment; and
 - a third function (P_M) representing a proportion of users that will perceive the telephonic voice connection as having much impairment, wherein $P_N + P_S + P_M = 1$.
20. The method of claim 18, wherein the at least one empirically derived mathematical function includes the equation:
- $$P_N = \exp [-a(x-c)^b],$$

wherein P_N represents a proportion of users that will perceive the telephonic voice connection as having no impairment, a and b are empirically derived constants, and c represents a noise level that substantially all users would perceive as being unacceptable.

21. The method of claim 18, wherein the at least one empirically derived mathematical function includes the equation:

$$P_M = 1 - \exp [-d(x-c)^e],$$

wherein P_M represents a proportion of users that will perceive the telephonic voice connection as having much impairment, d and e are empirically derived constants, and c represents a noise level that substantially all users would perceive as being unacceptable.

22. The method of claim 18, wherein the at least one empirically derived mathematical function includes the equation:

$$P_S = \exp [-a(x-c)^b] - \exp [-d(x-c)^e],$$

wherein P_S represents a proportion of users that will perceive the telephonic voice connection as having some impairment, a , b , d and e are empirically derived constants, and c represents a noise level that substantially all users would perceive as being unacceptable.

23. The method of claim 18, further comprising the step of providing a device for evaluating quality in a telephonic voice connection in a telecommunications network, the device includes a processor that is operative to calculate the solution to the at least one empirically derived mathematical function by using the at least one characteristic as an independent variable in the at least one empirically derived mathematical function.

24. The method of claim 23, further comprising the step of using the device to evaluate a portion of the telecommunications network.

25. The method of claim 24, wherein the portion of the telecommunications network is in service.

26. The device of claim 18, wherein the at least one characteristic is selected from the group consisting of C-message noise, magnitude of average power of speech, magnitude of average power of a quiet channel, echo path delay, echo path loss, a speech distortion indicator, and a dropped frame rate in a packet switched network.
27. The device of claim 18, wherein the network is a packet switched network
28. The device of claim 18, wherein the network is a circuit switched network.
29. A programmable device for evaluating quality in a telephonic voice connection in a telecommunications network, the device comprising:
- a memory operative to store at least one empirically derived mathematical function having at least one independent variable;
 - a processor coupled to the memory, the processor being operative to calculate a solution to the at least one empirically derived mathematical function by using at least one measured characteristic as the independent variable, whereby the solution is an estimate of likely user perception of the quality of the telephonic voice connection; and
 - an interface control circuit coupled to the memory, the interface control circuit being adapted to receive a revised at least one empirically derived mathematical function from an external device, and store the revised at least one empirically derived mathematical function in the memory.
30. The programmable device of claim 29, further comprising:
- a network interface, the network interface being operative to establish the telephonic voice connection between the device and the network; and
 - a measurement circuit coupled to the network interface, the measurement circuit being operative to measure the at least one measured characteristic of the telephonic voice connection.

31. The programmable device of claim 29, wherein the at least one empirically derived mathematical function includes the equation:

$$P_N = \exp [-a(x-c)^b],$$

wherein P_N represents a proportion of users that will perceive the telephonic voice connection as having no impairment, a and b are empirically derived constants, and c represents a noise level that substantially all users would perceive as being unacceptable.

32. The programmable device of claim 29, wherein the at least one empirically derived mathematical function includes the equation:

$$P_M = 1 - \exp [-d(x-c)^e],$$

wherein P_M represents a proportion of users that will perceive the telephonic voice connection as having much impairment, d and e are empirically derived constants, and c represents a noise level that substantially all users would perceive as being unacceptable.

33. The programmable device of claim 29, wherein the at least one empirically derived mathematical function includes the equation:

$$P_S = \exp [-a(x-c)^b] - \exp [-d(x-c)^e],$$

wherein P_S represents a proportion of users that will perceive the telephonic voice connection as having some impairment, a , b , d and e are empirically derived constants, and c represents a noise level that substantially all users would perceive as being unacceptable.

34. The device of claim 29, wherein the at least one characteristic is selected from the group consisting of C-message noise, magnitude of average power of speech, magnitude of average power of a quiet channel, echo path delay, echo path loss, a speech distortion indicator, and a dropped frame rate in a packet switched network.

35. The device of claim 29, wherein the network is a packet switched network

36. The device of claim 29, wherein the network is a circuit switched network.

37. A method for fabricating a device for evaluating quality in a telephonic voice connection in a telecommunications network, the method comprising:

empirically acquiring user perception data by having at least one test subject listen to a plurality of test messages, and rate the quality of each test message in accordance with at least one user perceived impairment characteristic;

modeling the user perception data as at least one mathematical function, the at least one mathematical function being graphically represented by a two dimensional curve having a shape, the shape of the curve being determined by a set of constants employed in the at least one mathematical function;

choosing values for the set of constants to thereby fit the two-dimensional curve to the user perception data to thereby generate at least one empirically derived mathematical function;

converting the at least one empirically derived mathematical function into a set of computer executable instructions; and

programming the device with the set of computer executable instructions.

38. The method of claim 37, wherein the step of empirically acquiring user perception data further comprises the steps of:

selecting a plurality of user perceived impairment characteristics;

selecting a plurality of quality characteristics of the voice signal, each of the quality characteristics affecting the quality of the voice signal as perceived and described by users;

generating a plurality of voice messages by varying selected ones of the plurality of quality characteristics;

acquiring user perception data by having the at least one test subject listen to the plurality of voice messages, the at least one test subject rating the quality of the plurality of voice messages in accordance with the plurality of user perceived impairment characteristics; and

transforming the each of the plurality of user perceived impairment characteristics into quantifications of each of the plurality of objective characteristics.

39. The method of claim 38, wherein the plurality of objective characteristics are selected from the group consisting of C-message noise, magnitude of average power of speech, magnitude of average power of a quiet channel, echo path delay, echo path loss, a speech distortion indicator, and a dropped frame rate in a packet switched network.

40. The method of claim 38, wherein the plurality of user perceived impairment characteristics includes volume level, noise level, speech distortion, and echo.

41. The method of claim 40, wherein the plurality of user perceived impairment characteristics are transformed into estimates, each estimate being a proportion of a population of users that would describe the telephonic voice connection as having no impairment, some impairment, or much impairment.

42. The method of claim 38, wherein the at least one empirically derived mathematical function includes a first function (P_N) representing a proportion of users that will perceive the telephonic voice connection as having no impairment, a second function (P_S) representing a proportion of users that will perceive the telephonic voice connection as having some impairment, and a third function (P_M) representing a proportion of users that will perceive the telephonic voice connection as having much impairment, where $P_N + P_S + P_M = 1$.

43. The method of claim 42, wherein the first function is characterized by the equation, $P_N = \exp [-a(x-c)^b]$.

44. The method of claim 43, wherein a and b are empirically derived constants, and c represents a noise level that substantially all users would perceive as being unacceptable.

45. The method of claim 42, wherein the third function is characterized by the equation, $P_M = 1 - \exp [-d(x-c)^e]$.

46. The method of claim 42, wherein d and e are empirically derived constants, and c represents a noise level that substantially all users would perceive as being unacceptable.

47. The method of claim 42, wherein the second function is characterized by the equation, $P_s = \exp [-a(x-c)^b] - \exp [-d(x-c)^e]$.

48. The method of claim 47, wherein a, b, d and e are empirically derived constants, and c represents a noise level that substantially all users would perceive as being unacceptable.

49. A computer readable medium having computer executable instructions for performing a method, the method comprising:

establishing a telephonic voice connection;

measuring at least one characteristic of the telephonic voice connection; and

calculating a solution to at least one empirically derived mathematical function by using at least one measured characteristic as an independent variable of the at least one empirically derived mathematical function.

50. The method of claim 49, wherein the solution is an estimate of likely user perception of the quality of the telephonic voice connection.

51. The method of claim 49, wherein the at least one empirically derived mathematical function includes the equation:

$$P_N = \exp [-a(x-c)^b],$$

wherein P_N represents a proportion of users that will perceive the telephonic voice connection as having no impairment, a and b are empirically derived constants, and c represents a noise level that substantially all users would perceive as being unacceptable.

52. The method of claim 49, wherein the at least one empirically derived mathematical function includes the equation:

$$P_M = 1 - \exp [-d(x-c)^e],$$

wherein P_M represents a proportion of users that will perceive the telephonic voice connection as having much impairment, d and e are empirically derived constants, and c represents a noise level that substantially all users would perceive as being unacceptable.

53. The method of claim 49, wherein the at least one empirically derived mathematical function includes the equation:

$$P_S = \exp [-a(x-c)^b] - \exp [-d(x-c)^e],$$

wherein P_S represents a proportion of users that will perceive the telephonic voice connection as having some impairment, a , b , d and e are empirically derived constants, and c represents a noise level that substantially all users would perceive as being unacceptable.

54. The method of claim 49, wherein the computer readable medium is selected from the group consisting of a DRAM, ROM, PROM, EEPROM, a hard drive, or compact disk.

55. The method of claim 49, wherein the method is performed by a telecommunications switching device coupled to the computer readable medium.

56. The method of claim 55, wherein the telecommunications switching device is disposed in a central office in a telecommunications network.

57. The method of claim 55, wherein the telecommunications switching device is a circuit switch.

58. The method of claim 55, wherein the telecommunications switching device is a packet switch.

59. The method of claim 49, wherein the method is performed by a Test Quality Measurement System (TQMS) coupled to the computer readable medium.
60. The method of claim 49, wherein the method is performed by a OEM equipment coupled to the computer readable medium.
61. A programmable device for evaluating quality in a telephonic voice connection in a telecommunications network, the device comprising:
- a memory operative to store at least one empirically derived mathematical function having at least one independent variable;
 - an interface control circuit coupled to the memory, the interface control circuit being adapted to receive revised empirically derived data from an external device, and store the revised empirically derived data in the memory; and
 - a processor coupled to the memory, the processor being programmed to calculate a revised at least one empirically derived mathematical function using the revised empirically derived data, and calculate a solution to the revised at least one empirically derived mathematical function by using at least one measured characteristic as the independent variable, whereby the solution is an estimate of likely user perception of the quality of the telephonic voice connection.

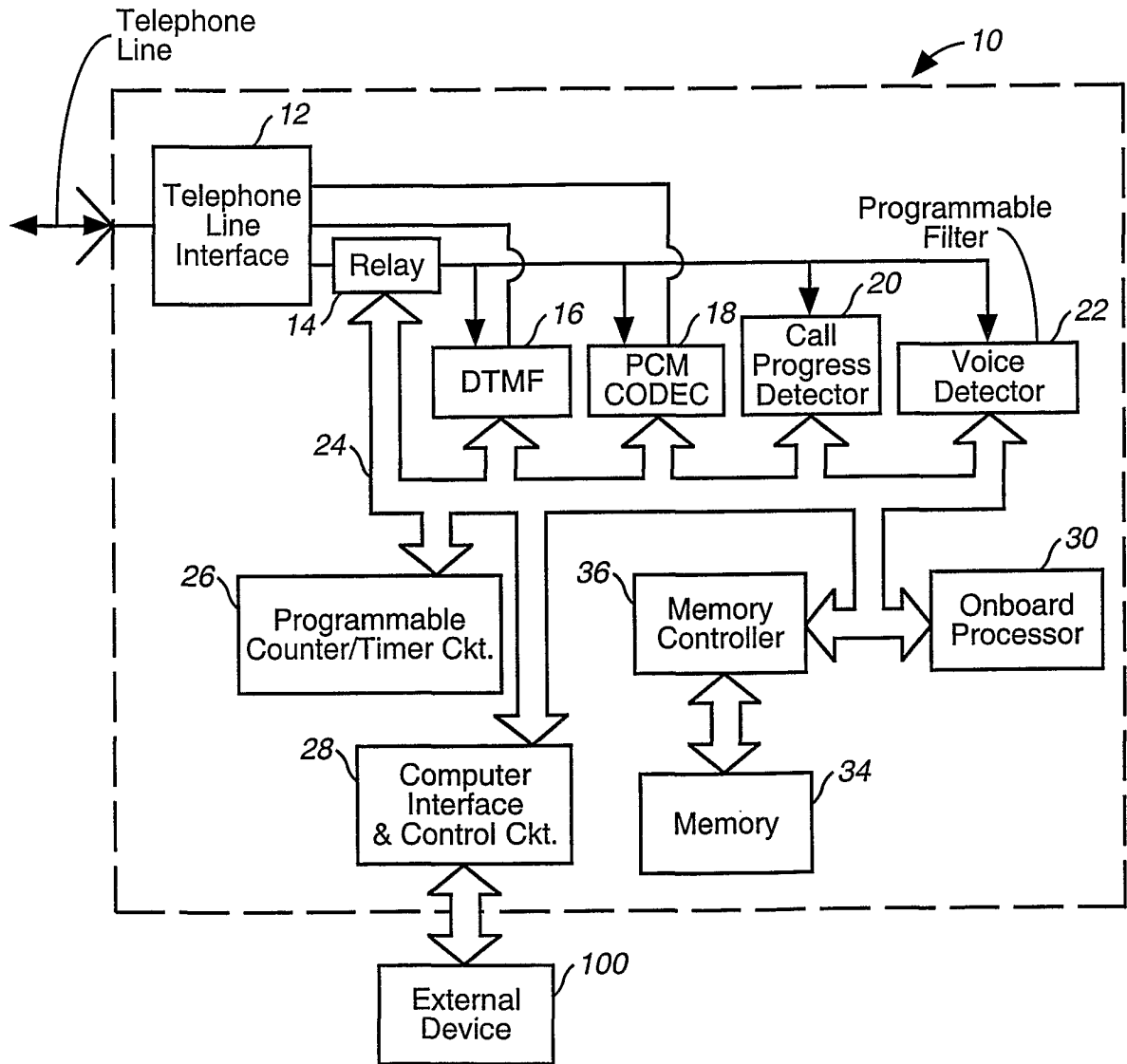


FIG. 1

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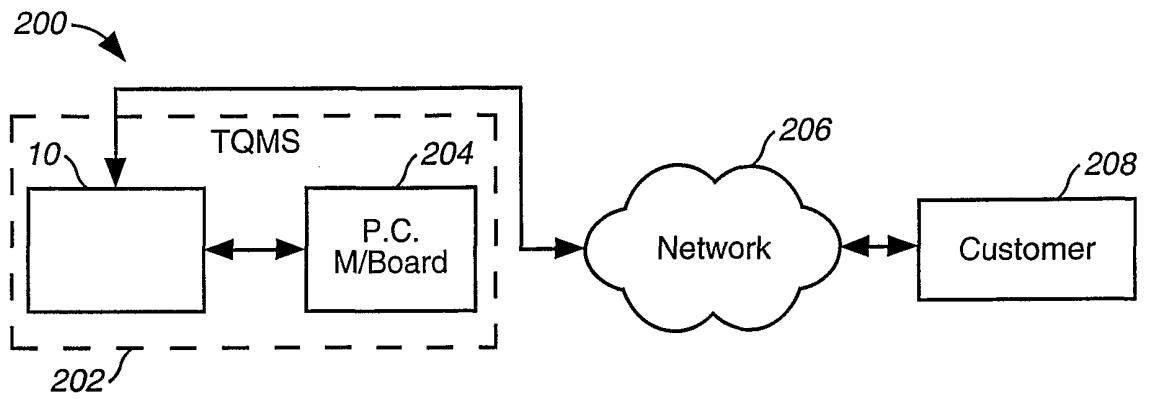


FIG. 2

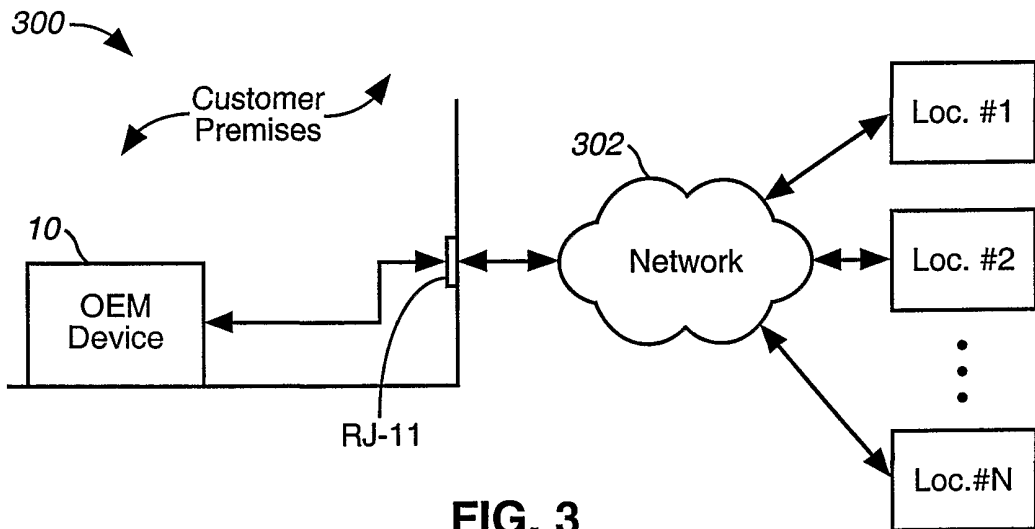


FIG. 3

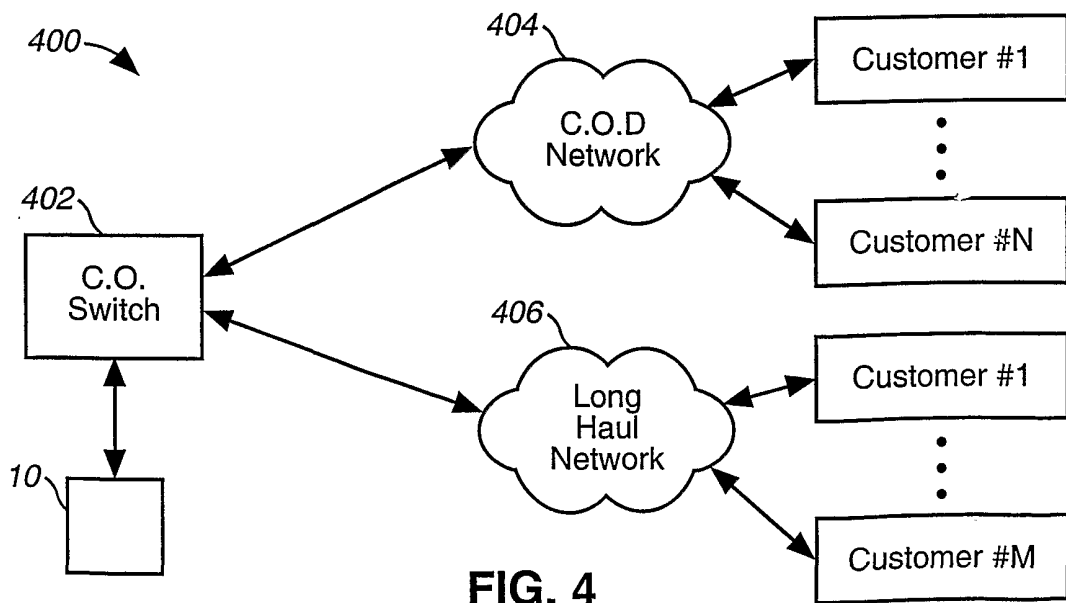


FIG. 4

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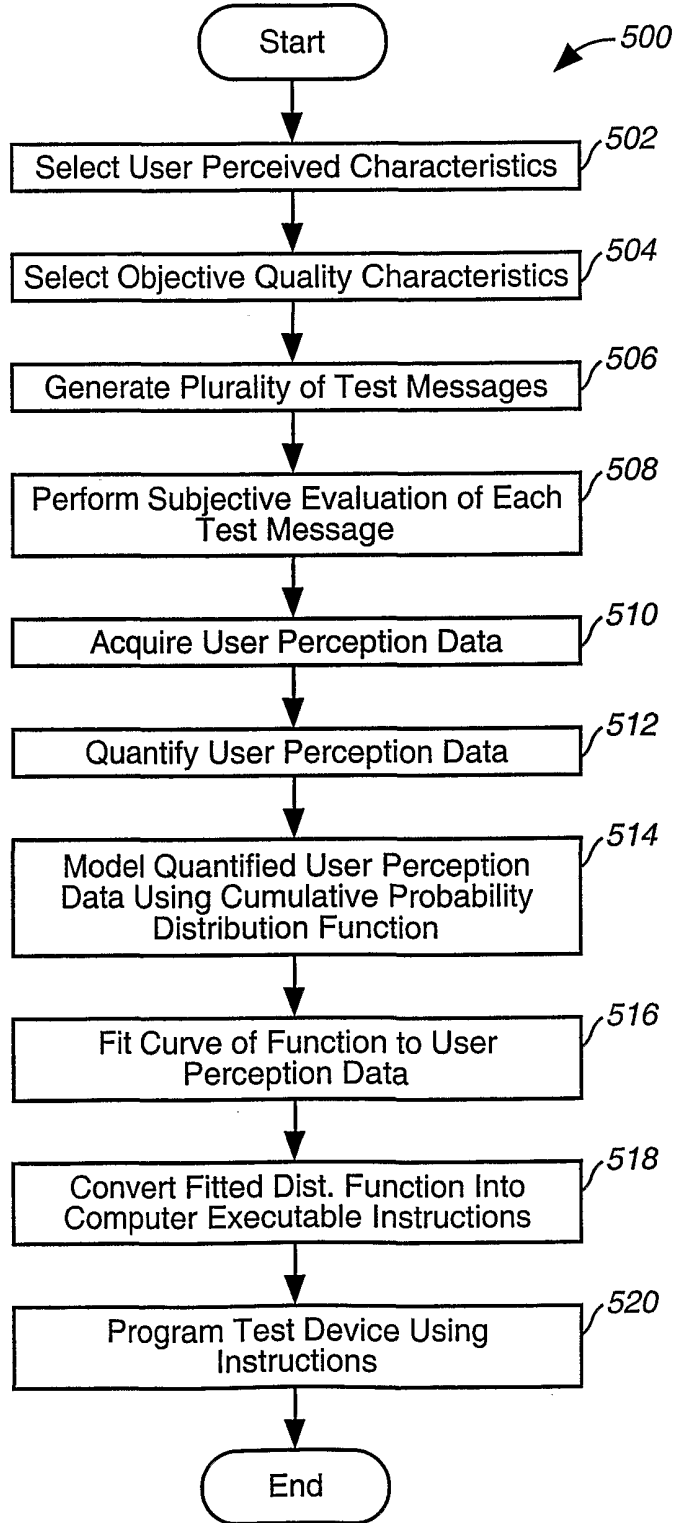


FIG. 5

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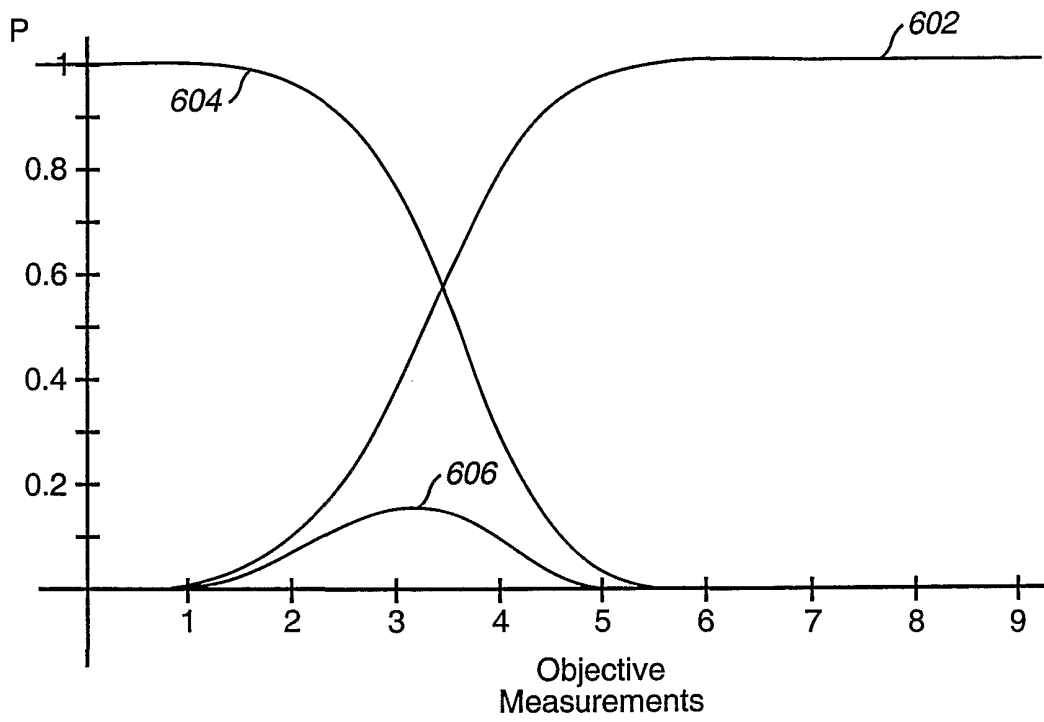


FIG. 6

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US02/03820

A. CLASSIFICATION OF SUBJECT MATTER																										
IPC(7) : HO4M 1/24																										
US CL : 379/1.02																										
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. : 379/1.02, 1.03, 1.04; 704/221, 228, 233																										
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,P	US 6,256,608 B1 (MALVAR) 03 July 2001(03.07.2001), abstract, figures 1-16, columns 1-22, especially column 19 lines 14-67.	1-61																								
Y,P	US 6,304,634 B1 (HOLLIER et al) 16 October 2001 (16.10.2001), abstract, figures 1-2, columns 1-16.	1-61																								
Y	US 5,572,570 A (KUENZIG) 05 November 1996 (5.10.1996), abstract, columns 1-16.	1-61																								
Y	US 5,742,929 A (KALLMAN et al) 21 April 1998 (21.04.1998), abstract, columns 1-2.	1-61																								
Y	US 5,835,565 A (SMITH et al) 10 November 1998 (10.11.1998), abstract, columns 1-11.	1-61																								
Y	US 5,933,475 A (COLEMAN) 03 August 1999 (03.08.1999), abstract, columns 1-22.	1-61																								
Y	US 5,867,813 A (DI PIETRO et al) 02 February 1999 (02.02.1999), abstract, columns 1-10, especially columns 7-9.	1-61.																								
Y	US 5,715,372 A (MEYERS et al) 03 February 1998 (03.02.1998), abstract, columns 1-10.	1-61																								
Y	US 5,479,576 A (WATANABE et al) 26 December 1995 (26.12.1995), abstract, columns 1-32.	1-61																								
<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 colspan="2">* Special categories of cited documents:</td> <td>"T"</td> <td>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</td> </tr> <tr> <td>"A"</td> <td>document defining the general state of the art which is not considered to be of particular relevance</td> <td>"X"</td> <td>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</td> </tr> <tr> <td>"E"</td> <td>earlier application or patent published on or after the international filing date</td> <td>"Y"</td> <td>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</td> </tr> <tr> <td>"L"</td> <td>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)</td> <td>"&"</td> <td>document member of the same patent family</td> </tr> <tr> <td>"O"</td> <td>document referring to an oral disclosure, use, exhibition or other means</td> <td></td> <td></td> </tr> <tr> <td>"P"</td> <td>document published prior to the international filing date but later than the priority date claimed</td> <td></td> <td></td> </tr> </table>			* Special categories of cited documents:		"T"	later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention	"A"	document defining the general state of the art which is not considered to be of particular relevance	"X"	document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone	"E"	earlier application or patent published on or after the international filing date	"Y"	document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art	"L"	document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"&"	document member of the same patent family	"O"	document referring to an oral disclosure, use, exhibition or other means			"P"	document published prior to the international filing date but later than the priority date claimed		
* Special categories of cited documents:		"T"	later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention																							
"A"	document defining the general state of the art which is not considered to be of particular relevance	"X"	document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone																							
"E"	earlier application or patent published on or after the international filing date	"Y"	document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art																							
"L"	document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"&"	document member of the same patent family																							
"O"	document referring to an oral disclosure, use, exhibition or other means																									
"P"	document published prior to the international filing date but later than the priority date claimed																									
Date of the actual completion of the international search 03 April 2002 (03.04.2002)		Date of mailing of the international search report 03 MAY 2002																								
Name and mailing address of the ISA/US Commissioner of Patents and Trademarks Box PCT Washington, D.C. 20231 Facsimile No. (703)305-3230		Authorized officer Curtis Kuntz <i>Kuntz</i> Telephone No. (703) 305-4700																								

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US02/03820

Box III TEXT OF THE ABSTRACT (Continuation of Item 5 of the first sheet)

A device (10) is disclosed that uses a continuous analysis function (514) representing mapping data relating object voice connection measurements to likely user perception of the quality of a voice connection. The device (10) is compact and inexpensive. It can be implemented on a single integrated circuit (18), or on a single printed circuit board. CPU (30) processing time is significantly reduced. The device (10) obtains a real-time estimate of likely user perception of a given connection in terms of a user perception rating system (514). The device (10) is reprogrammable, enabling it to be updated as more accurate mapping data is obtained.