US 20080122448A1

(19) United States
(12) Patent Application Publication
Pischl
(10) Pub. No.: US 2008/0122448 A1
(43) Pub. Date: May 29, 2008

(54) **METHOD AND SYSTEM FOR DETECTING TRANSFORMER SATURATION IN A COMMUNICATION INTERFACE**

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(21) Appl. No.: **11/563,349**

(22) Filed: **Nov. 27, 2006**

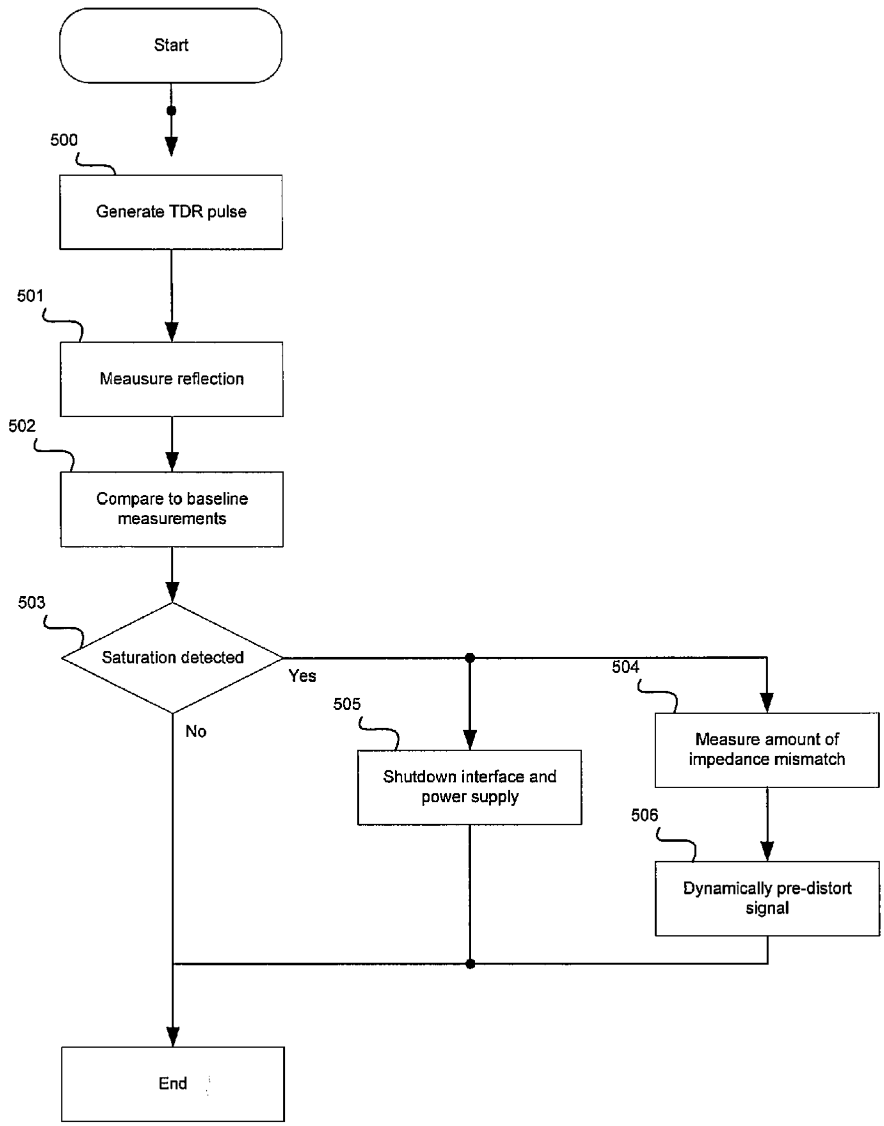
Publication Classification

(51) **Int. Cl.**
G01R 29/00 (2006.01)

(52) **U.S. Cl.** **324/600**

(57) **ABSTRACT**

A method and system for detecting transformer saturation in a communication interface is provided. The method may include detecting a change in impedance resulting from transformer saturation of at least one isolation transformer utilized in a network path of a network. The network may conform to an IEEE 802.3af specification where power may be delivered through the network. The method may further comprise generating a pulse at a one end of the network and measuring a reflection at that end to detect the transformer saturation. In response to the impedance change, a transmitter signal may be pre-distorted in order to compensate for the detected transformer saturation, or the power delivered over the network may be disabled.



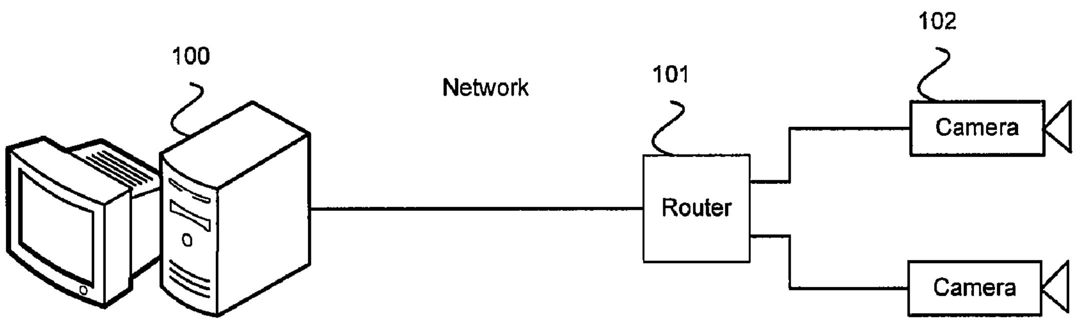


Fig. 1

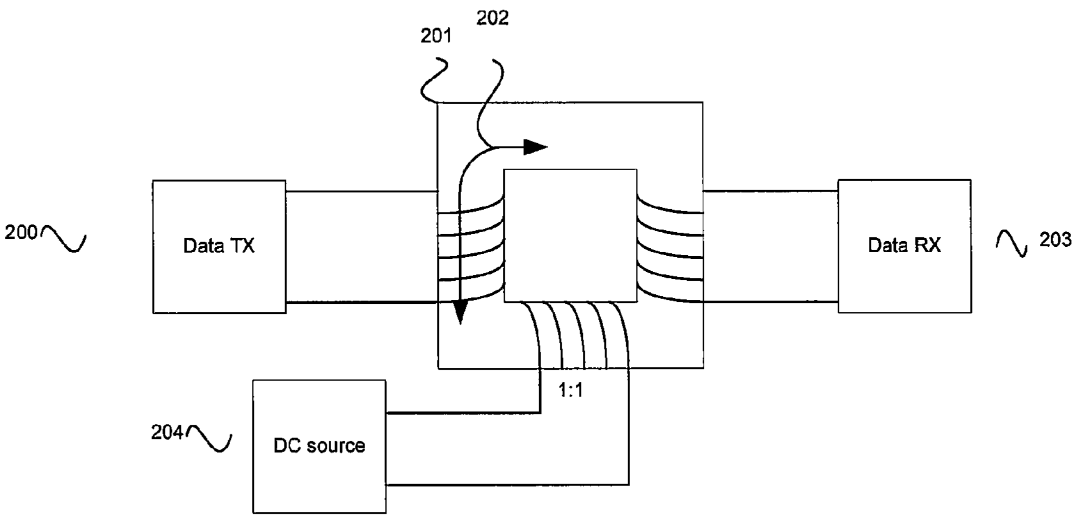

201
202
200
Data TX
Data RX
203
1:1
204
DC source

Fig. 2A

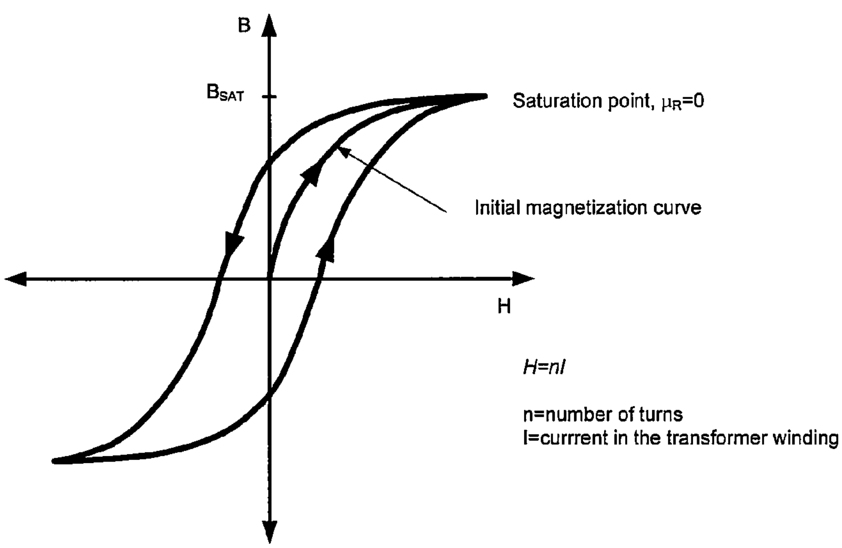

B
B_{SAT}
Saturation point, μ_R=0
Initial magnetization curve
H
H=nI
n=number of turns
I=currrent in the transformer winding

Fig. 2B

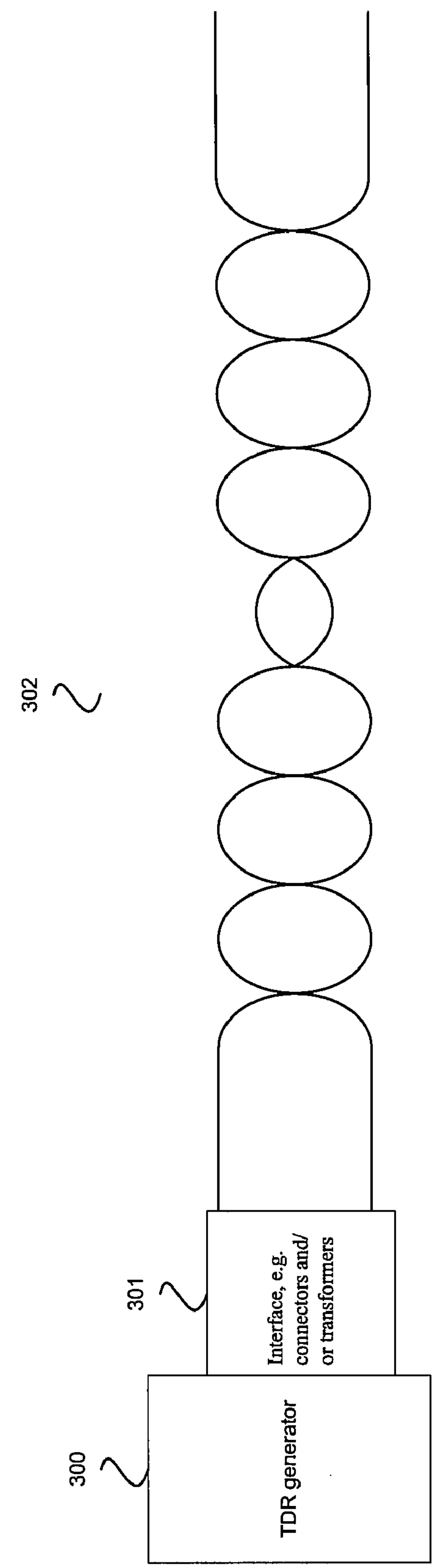

302
301
Interface, e.g. connectors and/ or transformers
300
TDR generator

Fig. 3

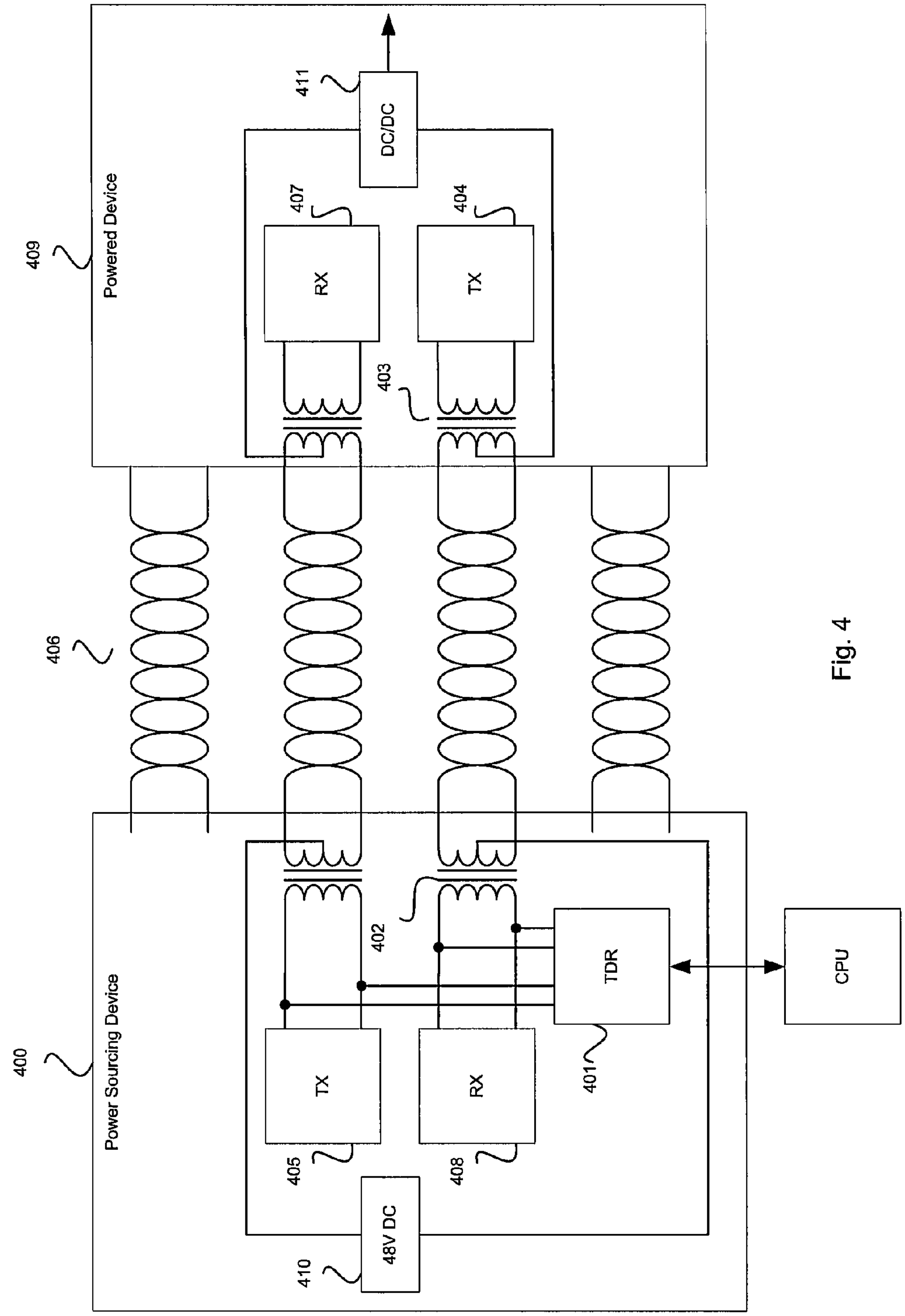

409
Powered Device
411
DC/DC
407
RX
404
TX
403
406
400
Power Sourcing Device
TX
RX
402
TDR
401
CPU
405
408
410
48V DC

Fig. 4

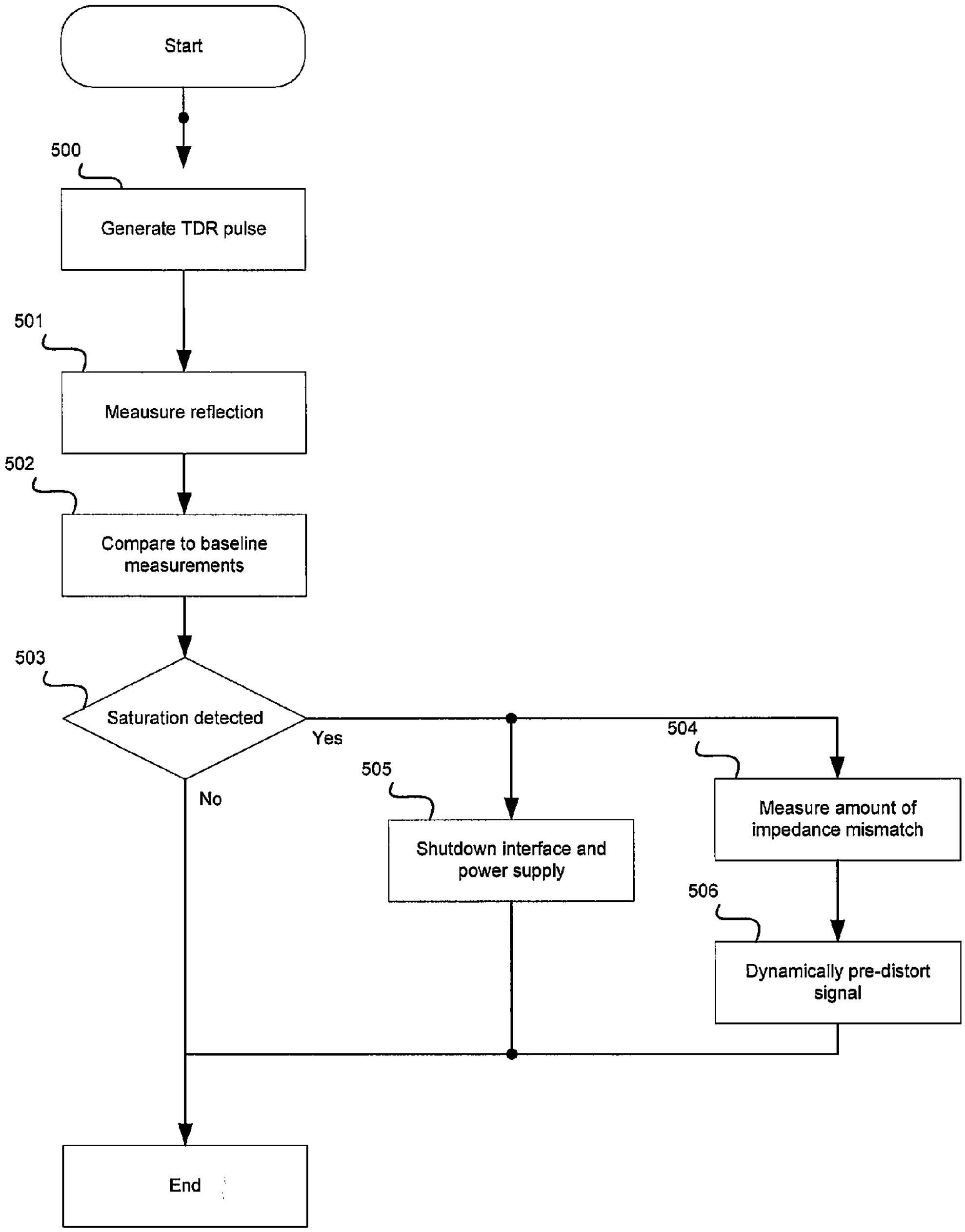

Start
500
Generate TDR pulse
501
Meausure reflection
502
Compare to baseline measurements
503
Saturation detected
Yes
No
505
Shutdown interface and power supply
504
Measure amount of impedance mismatch
506
Dynamically pre-distort signal
End

Fig. 5

METHOD AND SYSTEM FOR DETECTING TRANSFORMER SATURATION IN A COMMUNICATION INTERFACE

CROSS-REFERENCE TO RELATED APPLICATIONS/INCORPORATION BY REFERENCE

[0001] Not Applicable.

FIELD OF THE INVENTION

[0002] Certain embodiments of the invention relate to network communication systems. More specifically, certain embodiments of the invention relate to a method and system for detecting transformer saturation in a communication interface.

BACKGROUND OF THE INVENTION

[0003] Computer networks are continually being enhanced to improve the ways in which people communicate. For example, the Internet has enabled people to gain access to vast amounts of information. Besides the Internet, networks are utilized to facilitate the transfer of files between computers as well as to connect computers to printers, scanners, cameras and a whole host of other devices. The physical characteristics of the network can take on many different characteristics. For example, the actual connections may be made through coax or twisted pair cables. Routers and hubs may be utilized to connect multiple computers to one another and to direct network traffic. The protocol utilized by the network may vary. For example, the protocol may be TCP/IP, IPX/SPX, or AppleTalk.

[0004] Although most often thought of as a means for computers to communicate with one another, networks are now being utilized for other forms of communications. For example, in a security system, security cameras may communicate to a server computer via an IP network rather than stream analog video information over a video cable. This may make it easier to add security systems where an IP network already exists. Furthermore, in a networking environment, the computer and camera could be a great distance apart whereas the distance may be much shorter if the analog video were transferred directly over a cable.

[0005] Some network systems allow for the transfer of power over the network cable, by coupling DC voltages and currents to the conductors. For example, one way to transfer power may be to utilize unused conductors in the network cable. Another method may be to transfer the power utilizing the same conductors, but superimposing the power by utilizing isolation transformers. The second method may conform to IEEE 802.3af. This method may work well for most situations. However, under certain conditions the characteristics of the transformers may change and thus impede the transfer of data.

[0006] Further limitations and disadvantages of conventional and traditional approaches will become apparent to one of skill in the art, through comparison of such systems with some aspects of the present invention as set forth in the remainder of the present application with reference to the drawings.

BRIEF SUMMARY OF THE INVENTION

[0007] A system and/or method is provided for detecting transformer saturation in a communication interface substantially as shown in and/or described in connection with at least one of the figures, as set forth more completely in the claims.

[0008] These and other advantages, aspects and novel features of the present invention, as well as details of an illustrated embodiment thereof, will be more fully understood from the following description and drawings.

BRIEF DESCRIPTION OF SEVERAL VIEWS OF THE DRAWINGS

[0009] FIG. **1** is a block diagram of an exemplary arrangement for distributing power over an Ethernet connection, which may be utilized in connection with an embodiment of the invention.

[0010] FIG. **2**A is a block diagram of an exemplary circuit for communicating data via a transformer where the transformer is also utilized for power distribution, which may be utilized in connection with an embodiment of the invention.

[0011] FIG. **2**B is an exemplary graph of a hysteresis curve for a transformer, which may be utilized in connection with an embodiment of the invention.

[0012] FIG. **3** is an exemplary system for detecting faults in a network cable, in connection with an embodiment of the invention.

[0013] FIG. **4** is a block diagram of an exemplary arrangement for detecting transformer saturation in a communications interface, in accordance with an embodiment of the invention.

[0014] FIG. **5** is a block diagram of an exemplary flow diagram for detecting transformer saturation, in accordance with an embodiment of the invention.

DETAILED DESCRIPTION OF THE INVENTION

[0015] Certain embodiments of the invention may be found in a method and system for detecting transformer saturation in a communication interface. The method may include detecting a change in impedance resulting from transformer saturation of at least one isolation transformer utilized in a network path of a network. The network may conform to an IEEE 802.3af specification where power may be delivered through the network. The method may further comprise generating a pulse at a one end of the network and measuring a reflection at that end to detect the transformer saturation. In response to the impedance change, a transmitter signal may be pre-distorted in order to compensate for the detected transformer saturation, or the power delivered over the network may be disabled.

[0016] FIG. **1** is a block diagram of an exemplary arrangement for distributing power over an Ethernet connection, which may be utilized in connection with an embodiment of the invention. Referring to FIG. **1**, there is shown a computer **100**, a router **101**, and two cameras **102**. The computer **100** may comprise suitable logic, circuitry, and/or code that may enable communicating data over a network connection. For example, the computer **100** may comprise a network card and the network card may communicate utilizing an Ethernet standard, such as IEEE 802.3a. The network card may comprise suitable logic, circuitry, and/or code that may enable sending power over the same Ethernet connection. For example, the Ethernet connection may conform to IEEE 802.af. In this regard, the physical network connection may comprise a category 5 cable. This cable may, for example, have a total of 8 conductors or 4 twisted pair conductors. Two of the twisted pair conductors may be utilized for data communication and the other two may be unused. In some embodiments the unused conductors may, for example, be utilized to transfer power. In this regard, an output voltage of the power supply may be 48 volts DC. In other embodiments, the power may be distributed over the data lines.

[0017] The router **101** may comprise suitable logic, circuitry, and/or code that may enable routing data between a plurality of devices. For example, the router **101** may route data packets from the computer **100** to various end devices, such as the cameras **102** shown in FIG. **1**. In this regard, the connection between the computer **100** and the router **101** and the router **101** and the cameras may be an Ethernet connection as described above. To facilitate data transfers, the router **101** may require a power source. The router **101** may, for example, receive power from a power adapter plugged into a wall. The router **101** may also be capable of utilizing power transferred from the network card in the computer **100** and may be capable of outputting power for end devices, such as the cameras **102** shown in FIG. **1**.

[0018] The cameras **102** may comprise suitable logic, circuitry, and/or code that may enable capturing images and transferring those images over an Ethernet connection. In this regard the cameras **102** may be coupled to the router **101**. The cameras **102** may be capable of operating from power delivered over the Ethernet connection. In this regard, the cameras **102** may comprise additional logic, circuitry, and or code that may enable converting the power delivered over the Ethernet into voltages more suitable for powering each of the cameras **102** during operation.

[0019] FIG. **2**A is a block diagram of an exemplary circuit for communicating data via a transformer where the transformer is also utilized for power distribution, which may be utilized in connection with an embodiment of the invention. Referring to FIG. **2**A, there is shown a data TX **200**, a transformer **201**, a data RX **203**, a magnetic flux (H) within the transformer core **202**, and a DC source **204**.

[0020] FIG. **2**B is an exemplary graph of a hysteresis curve for a transformer, which may be utilized in connection with an embodiment of the invention. The central area of the curve may correspond to the "linear region" of the transformer **201**. H **202** may be proportional to the current in the transformer winding.

[0021] In operation, it may be necessary that the transformer **201** operate in the linear region. That is, it may be necessary that the signal-current operating point is around "zero" and that the maximum amplitude of the signal-current does not reach the area of saturation. When this is the case, the output signal on the secondary of the transformer **201** going to the data RX **203** may be linearly proportional to the TX signal from the data TX **200**.

[0022] If the signal-current reaches into the saturation area, distortions may occur, and transmission may not work properly. This may, for example, happen when the signal current-amplitude is too large. That is, this could occur even without a DC bias from the DC source **204** when the signal amplitude is too large. This may also occur, when the operating point of the transformer **201** is moved toward or into the saturation area by applying a DC-current to the transformer winding from the DC source **204**. A DC bias superimposed on one of the data-windings may also move the operating point of the transformer **201** toward saturation area, possible resulting in a distorted signal at the output of the transformer **201**.

[0023] FIG. **3** is an exemplary system for detecting faults in a network cable, in connection with an embodiment of the invention. Referring to FIG. **3**, there is shown a TDR (time domain reflectometer) **300**, a network cable **302**, and an interface **301**. The TDR **300** may work on the same principle as radar. A pulse of energy may be transmitted down a network cable **302**. When that pulse reaches the end of the network cable **302**, or a fault along the cable, part or all of the pulse energy may be reflected back to the TDR **300**. The TDR **300** may measure the amount of time it takes for the signal to travel down the network cable **302**, reflect off an impedance discontinuity, and reflect back. It may also compare the waveform of the launched pulse and the received reflection. The TDR **300** may then convert this time to distance, as well as the reflected waveform, and display the information as a location and magnitude and type of impedance (real, capacitive, inductive) discontinuity along the network cable **302**.

[0024] A TDR **300** may measure a change in impedance, which may be caused by a variety of reasons. For example, the change in impedance may be related to network cable **302** damage, change in cable type, or improper installation. The change in impedance may also be the result of defective manufacturing. In this regard, the impedance of the cable may be determined by the spacing of the conductors from each other and the type of dielectric utilized. If the conductors are manufactured with exact spacing and the dielectric is, for example, exactly constant, the cable impedance may be constant. The cable impedance may vary along the line if, for example, the conductors are kinked, the spacing between the conductors is changed, or a component with improper impedance is connected anywhere along the line.

[0025] The TDR **300** may operate by sending electrical pulses down the cable and sampling the reflected energy. Any impedance change may cause some energy to reflect back toward the TDR **300** and may be displayed on the TDR **300**. The characteristics of the reflected signal may be utilized to determine the amount of change in impedance.

[0026] FIG. **4** is a block diagram of an exemplary arrangement for detecting transformer saturation in a communications interface, in accordance with an embodiment of the invention. Referring to FIG. **4**, there is shown a power sourcing device (PSD) **400**, a network cable **406**, and a powered device (PD) **409**. Referring to the PSD, there is shown a PSD transmitter **405**, a PSD receiver **408**, an isolation transformer **402**, a power supply **410**, and a TDR **401**. Referring to the PD **400**, there is shown a PD transmitter **404**, a PD receiver **407**, and a DC/DC converter **411**.

[0027] The PSD **400** may comprise suitable logic, circuitry, and or code that may enable communication of data over an interface as well as delivering power over the same interface. For example, the PSD **400** may be a network interface card (NIC) in a computer **100** (FIG. **1**). The PSD transmitter **405** may comprise suitable logic, circuitry, and/or code that may enable conversion of data to a suitable transmission format so that it may be transferred long distances. For example, a computer **100** may input data bits into the PSD transmitter **405** and the PSD transmitter **405** may output a differential voltage corresponding to the data bits. The PSD receiver **408** may comprise suitable logic, circuitry, and/or code that may enable converting data communicated from a remote transmitter back into a format suitable for a computer. The PSD transmitter **405** and PSD receiver **408** may be coupled to the PSD isolation transformers **402**.

[0028] The PSD isolation transformers **402** and the PD isolation transformers **403** may comprise several windings and a core that may enable isolation of DC voltages that may be present on the primary and secondary. The isolation transformers **402** may have characteristics similar to the transformer shown in FIG. **2**A. The windings of the isolation transformers **402** may be center tapped. In the PSD **400**, the center taps may be coupled to the DC power supply **410**. In the PD **409**, the center taps may be coupled to the DC/DC converter **411**. The other taps may be coupled to the network cable **406**.

[0029] The network cable **406** may comprise several conductors that may enable communication of data as well as delivery of power. The network cable **406** may correspond to a category 5 cable. In this regard, the network cable **406** may comprise 4 sets of twisted pair cables. Two of the twisted pair cables may be utilized to communicate data between, for example, the PSD **400** and the PD **409**. The same twisted pair cables may also be utilized to deliver power from the PSD **400** to the PD **409**. The ends of the network cable **406** may be coupled to the isolation transformers **402** in the PSD **400** and the isolation transformers **403** in the PD **409**.

[0030] The PD transmitter **404** may comprise suitable logic, circuitry, and/or code that may enable conversion of data to a suitable transmission format so that it may be transferred over long distances. For example, a computer may input data bits into the PD transmitter **404** and the PD transmitter **404** may output a differential voltage corresponding to the data bits. The PD receiver **407** may comprise suitable logic, circuitry, and/or code that may enable converting data communicated from a remote transmitter back into a format suitable for a computer. The PD transmitter **404** and PD receiver **407** may be coupled to the PSD isolation transformers **403**.

[0031] The power supply **410** may comprise suitable logic, circuitry, and/or code that may enable the generation of power to power a remote device. In this regard, the power supply **410** may generate, for example, 48 volts. The power supply **410** may be coupled to the center taps on the secondaries of the PSD isolation transformers **402** in the PSD **400**.

[0032] The DC/DC converter **411** may comprise suitable logic, circuitry, and/or code that may enable the conversion of voltage from one DC voltage to another DC voltage. In this regard, the DC/DC converter **411** may input 48 volts and may output a voltage sufficient to power the PD **409**. For example, the output of the DC/DC converter **411** may be 5 volts or 12 volts. The output may also be greater than the input voltage. The DC/DC converter **411** may be coupled to the center taps on the secondaries of the PSD isolation transformers **403** in the PD **409**.

[0033] The TDR **401** may comprise suitable logic, circuitry, and/or code that may enable the detection of faults in a communication path. In this regard, the TDR **401** may correspond to the TDR shown in FIG. **3**. The TDR **401** may reside within the PSD **400** and may be coupled to the primary side of the PSD isolation transformers **402**. The TDR may transmit a pulse through the PSD isolation transformers **402** and measure the reflections caused by changes in impedance between the PSD **400** and the PD **400**. In this regard, the TDR may be capable of detecting changes in the impedance of the isolation transformers **402** and **403** as well as defects in the network cable **406** or whether or a component with improper impedance is connected anywhere along the line.

[0034] In operation, the power supply **410** in the PSD **400** may be utilized to supply power to a PD **409**. The power may be transferred via the same twisted pair cables utilized for communication between the PSD **400** and the PD **409**. The power may be superimposed on the communication signals by inserting the power into the center taps on the secondaries of the PSD isolation transformers **402**. As a result, the signals traveling over the twisted pair may take on a DC bias equal to the power supply **410** voltage. This DC bias may be removed by PD isolation transformers **403**.

[0035] In certain instances, DC current through the transformer may cause the transformer core to saturate by, for example, the mechanism shown FIG. **2**A and FIG. **2**B. This may happen even if the level of the DC current is within the operating specification for the PSD **400** and PD **409**. It may depend on the transformer, contact resistance of the connector utilized and resistance of the conductors in the cable.

[0036] The TDR **401** may be utilized to detect when the transformer impedance changes. For example, it may be utilized to detect relative changes in the impedance of the isolation transformers **402** and **403** before and after a DC current has been applied. For example, the TDR **401** may detect if the DC current is saturating the core and thus causing an impedance drop, which may have a negative impact on the quality and possibility of data transmission through the isolation transformers **402** and **403**. It may do this by generating pulses on either the PSD **400** or PD **409** side of the isolation transformers **402** and **403** and then measure the reflection off the isolation transformers **402** and **403**. If saturation is detected then, for example, a CPU may reduce or eliminate the current delivered to PD or flag an error and/or warning signal that the data transmission may be affected.

[0037] In another embodiment of the invention, the signal may be intentionally pre-distorted when, for example, saturation is detected. For example, the PSD transmitter **405** may pre-distort the output signals so that when they pass through the saturating isolation transformers, the signals appear proper at the receiving end. The PSD transmitter **405** may also be capable of pre-distorting the signal in proportion to an amount of detected saturation.

[0038] In yet another embodiment of the invention, a TDR **401** may reside within the PD **409** and be coupled to the primary side of the isolation transformers **403**. This may enable the PD **409** to detected transformer saturation as well.

[0039] FIG. **5** is a block diagram of an exemplary flow diagram for detecting transformer saturation, in accordance with an embodiment of the invention. At step **500**, the TDR **401** may generate a pulse so that reflections may be measured. The optimal pulse characteristics may depend on the characteristics of the isolation transformers **402** and **403**, the location of the transformer relative to the transceiver and on the characteristics of the interconnects used for the signal transmission, which may include PCB traces and other cables that may be utilized. At step **501**, the TDR **401** may measure the reflections and at step **502**, the TDR **401** may compare the measurements to baseline measurements. For example, during initial setup, the TDR **401** may have measured the impedance of the connection between the PSD **400** and the PD **409**. This measurement may take into account the impedance of the isolation transformers **402** and **403** as well as the impedance of the network cable **406**. The TDR **401** may store this information so that it may be utilized as a baseline measurement for later measurements.

[0040] At step **503**, the TDR **401** may check if the connection between the PSD **400** and PD **409** matches the base line impedance. If the values don't match, then one or more of the isolation transformers **402** and **403** may be in saturation. The result of the comparison may be communicated to a CPU so that the CPU may take appropriate action.

[0041] If saturation has been detected then, at step **505** the CPU may shutdown communication and disable the power supply **410**. The CPU may also report an error to the user so that the user may take care of the problem. In another embodiment of the invention, if saturation has been detected, then at step **504** the amount of the impedance mismatch may be determined. Then at step **506**, this amount of mismatch may be utilized to dynamically pre-distort the signals. The pre-distortion may take place within the PSD transmitter **405**. In this manner PSD **400** may compensate for the saturation.

[0042] Another embodiment of the invention may provide a method for performing the steps as described herein for detecting transformer saturation in a communication interface. For example, a change in the impedance of an isolation transformer **402** utilized in a network, resulting from transformer saturation may be detected by generating a pulse at one end of the network and measuring the reflection that corresponds to the isolation transformer **402**. The network may conform to an IEEE 802.3af specification where power may be delivered through the network be DC power supply **410**. In response to the impedance change, a transmitter signal may be pre-distorted by a transmitter **405** in order to compensate for the detected transformer saturation, or the power delivered over the network may be disabled.

[0043] Accordingly, the present invention may be realized in hardware, software, or a combination of hardware and software. The present invention may be realized in a centralized fashion in at least one computer system, or in a distributed fashion where different elements are spread across several interconnected computer systems. Any kind of computer system or other apparatus adapted for carrying out the methods described herein is suited. A typical combination of hardware and software may be a general-purpose computer system with a computer program that, when being loaded and executed, controls the computer system such that it carries out the methods described herein.

[0044] The present invention may also be embedded in a computer program product, which comprises all the features enabling the implementation of the methods described herein, and which when loaded in a computer system is able to carry out these methods. Computer program in the present context means any expression, in any language, code or notation, of a set of instructions intended to cause a system having an information processing capability to perform a particular function either directly or after either or both of the following: a) conversion to another language, code or notation; b) reproduction in a different material form.

[0045] While the present invention has been described with reference to certain embodiments, it will be understood by those skilled in the art that various changes may be made and equivalents may be substituted without departing from the scope of the present invention. In addition, many modifications may be made to adapt a particular situation or material to the teachings of the present invention without departing from its scope. Therefore, it is intended that the present invention not be limited to the particular embodiment disclosed, but that the present invention will include all embodiments falling within the scope of the appended claims.

What is claimed is:

1. A method for processing signals in a communication system, the method comprising: detecting a change in impedance resulting from transformer saturation of at least one transformer utilized in a network path of a network.

2. The method according to claim **1**, comprising generating at least one pulse at a first end of said network path and measuring at least one reflection at said first end.

3. The method according to claim **1**, comprising pre-distorting a signal in response to said detecting.

4. The method according to claim **1**, comprising delivering power through said network path via said at least one transformer.

5. The method according to claim **4**, comprising disabling said delivered power in response to said detecting.

6. The method according to claim **1**, wherein said at least one transformer is an isolation transformer.

7. The method according to claim **1**, wherein said impedance change is related to a saturation level of said transformer.

8. The method according to claim **1**, wherein said network conforms to an IEEE 802.3af specification.

9. The method according to claim **1**, comprising generating a signal to compensate for said transformer saturation upon said detecting.

10. A machine-readable storage having stored thereon, a computer program having at least one code section for processing signals in a communication system, the at least one code section being executable by a machine for causing the machine to perform steps comprising: detecting a change in impedance resulting from transformer saturation of at least one transformer utilized in a network path of a network.

11. The machine-readable storage according to claim **10**, wherein said at least one code section comprises code that enables generating at least one pulse at a first end of said network path and measuring at least one reflection at said first end.

12. The machine-readable storage according to claim **10**, wherein said at least one code section comprises code that enables pre-distorting a signal in response to said detecting.

13. The machine-readable storage according to claim **10**, wherein said at least one code section comprises code that enables delivering power through said network path via said at least one transformer.

14. The machine-readable storage according to claim **13**, wherein said at least one code section comprises code that enables disabling said delivered power in response to said detecting.

15. The machine-readable storage according to claim **10**, wherein said at least one transformer is an isolation transformer.

16. The machine-readable storage according to claim **10**, wherein said impedance change is related to a saturation level of said transformer.

17. The machine-readable storage according to claim **10**, wherein said network conforms to an IEEE 802.3af specification.

18. The machine-readable storage according to claim **10**, wherein said at least one code section comprises code that enables generating a signal to compensate for said transformer saturation upon said detecting.

19. A system for processing signals in a communication system, the system comprising: one or more circuits that enables detecting a change in impedance resulting from transformer saturation of at least one transformer utilized in a network path of a network.

20. The system according to claim **19**, wherein said one or more circuits enables generating at least one pulse at a first end of said network path and measuring at least one reflection at said first end.

21. The system according to claim **19**, wherein said one or more circuits enables pre-distorting a signal in response to said detecting.

22. The system according to claim **19**, wherein said one or more circuits enables delivering power through said network path via said at least one transformer.

23. The system according to claim **22**, wherein said one or more circuits enables disabling said delivered power in response to said detecting.

24. The system according to claim **19**, wherein said at least one transformer is an isolation transformer.

25. The system according to claim **19**, wherein said impedance change is related to a saturation level of said transformer.

26. The system according to claim **19**, wherein said network conforms to an IEEE 802.3af specification.

27. The system according to claim **19**, wherein said one or more circuits enables generating a signal to compensate for said transformer saturation upon said detecting.

* * * * *