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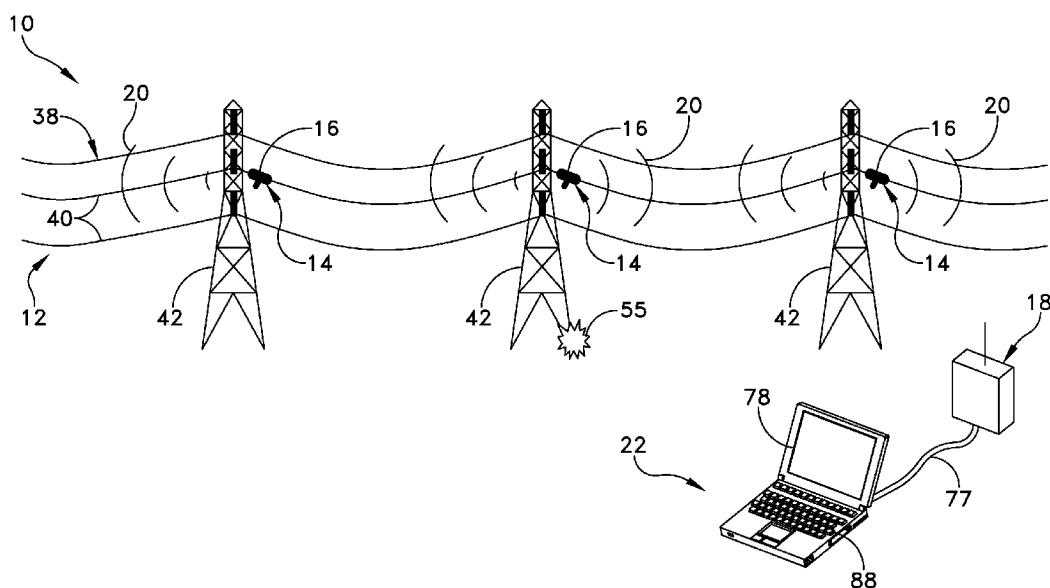
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(54) Title: METHODS, APPARATUS, AND SYSTEMS FOR MONITORING TRANSMISSION SYSTEMS



(57) Abstract: A sensing platform for monitoring a transmission system may include a sensor that senses one or more conditions relating to a condition of the transmission system or and/or the condition of an environment around the transmission system. A control system operatively associated with the sensor produces output data based on an output signal produced by the sensor. A transmitter operatively associated with the control system transmits the output data from the control system.

METHODS, APPARATUS, AND METHODS FOR MONITORING TRANSMISSION SYSTEMS

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Related Applications

This application claims benefit of U.S. Non-provisional application No. 11/425,287, filed June 20, 2006, entitled METHODS, APPARATUS, AND METHODS FOR MONITORING TRANSMISSION SYSTEMS, which is incorporated herein by reference in its entirety.

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Contractual Origin of the Invention

This invention was made with United States Government support under Contract No. DE-AC07-05ID14517 awarded by the United States Department of Energy. The United States Government has certain rights in the invention.

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Technical Field

This invention relates to sensing systems in general and more specifically to methods, apparatus, and systems for monitoring transmission systems.

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Background

Transmission systems, such as pipelines, cell towers and electrical power transmission systems, can be damaged in a variety of ways, including damage by weather, by accidents, and by intentional sabotage, just to name a few. Of course, many elements of such transmission systems are often located in remote areas where monitoring of the systems may

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be quite difficult, dangerous, and expensive. However, damage to these transmission systems can result in even more costly and extensive repairs. For example, damage to multiple towers of an electrical power transmission system could cause cascading or ‘rolling’ blackouts.

Early notification of damage to a transmission system can provide several benefits. If a transmission system operator is informed that an event is forthcoming then the operator can follow a procedure for mitigating the consequences of that event. For electrical power transmission systems, for example, an operator could take steps to localize the problem, thus minimizing or preventing the occurrence of cascading blackouts. Additionally, if an operator is informed that an event, such as intentional sabotage, is happening at a given location, the operator can alert local law enforcement authorities so that the intruder may be captured. Monitoring of transmission systems may also provide an opportunity for enhancing security or monitoring of remote locations, such as border areas.

Summary of the Invention

One embodiment of a sensing platform for monitoring a transmission system may comprise a sensor that senses one or more conditions relating to a condition of the transmission system or and/or the condition of an environment around the transmission system. A control system operatively associated with the sensor produces output data based on an output signal produced by the sensor. A transmitter operatively associated with the control system transmits the output data from the control system.

A system for monitoring a transmission system may comprise a plurality of sensing platforms operatively associated with the transmission system at a corresponding plurality of locations along the transmission system. Each sensing platform may include a sensor that

senses one or more conditions of the transmission system, a control system that produces output data based on output signals from the sensor, and a transceiver that transmits the output data from the control system. At least one endpoint receiver receives the output data transmitted by a sensing platform.

5 A method for monitoring a transmission system may involve the steps of: Sensing
one or more conditions of the transmission system and/or an environment around the
transmission system, and transmitting data related to the sensed condition.

10 Brief Description of the Drawing

Illustrative and presently preferred embodiment of the invention are shown in the accompanying drawing in which:

Figure 1 is a pictorial representation of a system for monitoring a transmission system according to one embodiment of the invention;

Figure 2 is a side view in elevation of one embodiment of a sensing platform with a portion of the housing broken-away to reveal the internal subsystems and components;

Figure 3 is an exploded perspective view of the sensing platform illustrated in Figure 2;

Figure 4 is a schematic block diagram of the sensing platform illustrated in Figures 2
20 and 3;

Figure 5 is a schematic block diagram of a data processing routine utilized by the control system; and

Figure 6 is a schematic block diagram of an analysis routine.

Detailed Description of the Preferred Embodiments

One embodiment of a monitoring system 10 is shown in Figure 1 as it may be used to monitor a portion, or even substantially the entirety, of a transmission system 12. By way of example, in one embodiment, the transmission system 12 may comprise an electrical power transmission system 38, although the invention may be used with other types of transmission systems as well. Briefly, the monitoring system 10 may comprise a plurality of individual sensing platforms 14 provided at various locations 16 along the transmission system 12. Monitoring system 10 may also comprise at least one endpoint receiver 18. Endpoint receiver 18 may be positioned so that it receives information 20 transmitted by at least one of the plurality of sensing platforms 14. In the embodiment shown and described herein, endpoint receiver 18 may be operatively associated with a user interface system 22, such as, for example, a personal computer, to allow a user (not shown) to interpret and/or act on the information 20 received by endpoint receiver 18. In addition, and as will be described in greater detail below, user interface system 22 may also allow the user to transmit information or programming instructions to the various sensing platforms 14.

Referring now primarily to Figures 2-4, each sensing platform 14 may be identical to the others (although this need not be the case), and may comprise a chassis or housing 24 sized to receive the various components and subsystems comprising the individual sensing platform 14. For example, in one embodiment, the sensing platform 14 may comprise at least one sensor 26, a control system or processor 28, and a transmitter 30. The sensing platform 14 also may be provided with a receiver 32, in which case the combination of the transmitter 30 and receiver 32 may be referred to herein in the alternative as a transceiver 34.

The one or more sensors 26 comprising the sensing platform 14 may be used to sense one or more conditions of the transmission system 12 and/or one or more conditions of an environment around the transmission system 12. In one embodiment, the control system or processor 28 is operatively associated with the sensor(s) 26 and is also responsive to an output signal(s) 36 produced by the sensor(s) 26 that relates to the sensed condition(s). The control system 28 produces information 20 that relates to or is derived from the sensed condition. The transmitter 30 is then used to transmit the information 20 produced by the control system 28.

The sensing platform 14 may also be provided with a power conversion system 72. Power conversion system 72 extracts energy from the transmission system 12 and converts it into a form useable by the sensing platform 14. For example, in an embodiment wherein the transmission system 12 comprises an electrical power transmission system 38, the power conversion system 72 may comprise an inductive power converter 74. Briefly, inductive power converter 74 may comprise a wire coil 76 positioned so that it is within an alternating magnetic field (shown schematically at “B” in Figure 4) surrounding an electrical conductor 40 of the electrical power transmission system 38. The alternating magnetic field B induces an alternating electric current in wire coil 76 which may then be rectified and/or regulated by the inductive power converter 74 so that it is useable by the sensing platform 14.

In a typical operational example, each sensing platform 14 monitors at least one condition of the transmission system 12, such as, for example, vibrations detected in the transmission system 12 due to an event 55 occurring on or nearby tower 42. See Figure 1. Alternatively, each sensing platform 14 may monitor at least one condition of an environment around the transmission system 12, such as, for example, an ambient temperature or light in

the infra-red wavelength range that may be emitted by various objects or persons in the environment around the transmission system 12. The control system 28 of each sensing platform 14 may be configured to evaluate or analyze the output signals 36 produced by the sensor or sensors 26 to produce information 20. For example, in one embodiment, the control
5 system 28 analyzes the output signal(s) 36 from the sensor(s) 26 to determine whether the sensed condition is a normal condition or an anomalous condition. If the sensed condition is determined to be an anomalous condition, the control system 28 may operate the transmitter 30 of the sensing platform 14 to transmit information 20. The transmitted information 20 is ultimately received by the endpoint receiver 18. If the sensed condition is determined to be a
10 normal condition, then no information need be sent, although it could be.

In this regard it should be noted that, in a typical embodiment, the endpoint receiver 18 will be located at a position beyond the transmitting range of most of the individual sensing platforms 14. Therefore, in order to ensure that the transmitted signal from any one of the individual sensing platforms 14 will be received by the endpoint receiver 18, each
15 sensing platform 14 may be provided with a transceiver 34 (i.e., a transmitter 30 and a receiver 32). Consequently, in an embodiment wherein the monitoring system 10 comprises a plurality of sensing platforms 14 having such transceivers 34, signals transmitted by one sensing platform 14 may be received by one or more nearby sensing platforms 14. The
nearby sensing platform(s) 14 may then re-transmit the signal. See Figure 1. In this manner,
20 the transmitted signal may be relayed by various ones of the sensing platforms 14 comprising the monitoring system 10 until the signal is ultimately received by the endpoint receiver 18.

Additional redundancy may be realized by providing the system 10 with two or more endpoint receivers 18 located at different positions along the transmission system 12. If, for

some reason, the signal from a sensing platform 14 fails to be relayed by nearby sensing platforms 14 along one direction, (thus fails to reach a first endpoint receiver 18), the signal from sensing platform 14 relayed by nearby sensing platforms in the other direction may be received by a second endpoint receiver 18 located at the different position. Of course, the provision of additional endpoint receivers 18 at various points along the transmission system 12 may provide additional measures of redundancy.

Once the information 20 is received by the endpoint receiver 18 it may be presented in human-readable form, thereby allowing a user or system operator to interpret and/or act upon the information 20, as the case may be. In the embodiment shown and described herein, the endpoint receiver 18 is operatively associated with a user interface system 22 for this purpose. The user interface system 22 may present the received information 20 on a display system 78. For example, if the information 20 relates to an anomalous condition (e.g., event 55, Figure 1) detected by one or more of the sensing platforms 14, the user interface system 22 may provide an indication about the anomalous condition, what it may relate to (e.g., vibrations, temperature, or infra-red signature), as well as the particular sensing platform or platforms 14 that detected the anomalous condition. Additional information, data, and options may also be provided by user interface system 22, as will be described in further detail herein.

One advantage of the present invention is that it may be used to monitor a transmission system 12 and to provide to an endpoint receiver 18 information 20 regarding one or more monitored conditions. In one exemplary embodiment, the information 20 regarding the one or more monitored conditions may be evaluated by a user to make a determination about whether the integrity of the transmission system 12 is, or may soon be, compromised. Alternatively, in another exemplary embodiment, a user may utilize the

information 20 about the monitored condition or conditions for purposes other than evaluating the integrity and security of the transmission system 12. For example, the information 20 provided by one or more of the sensing platforms 14 may be utilized to derive information about the passage of persons or vehicles within sensing range of one or more of the individual sensing platforms 14. Still other purposes and variations are possible, as would become apparent to persons having ordinary skill in the art after having become familiar with the teachings provided herein. Consequently, the methods, apparatus, and systems shown and described herein should not be regarded as limited to any particular purpose.

Still other advantages are associated with the power conversion system 72 which may be provided in each of the sensing platforms 14. For example, deriving from the transmission system 12 the energy required to operate the individual sensing platforms 14 dispenses with the need to provide each individual sensing platform 14 with a separate power supply (e.g., a storage battery) capable of operating the sensing platform 14. Accordingly, the power conversion system 72 will allow the individual sensing platforms 14 to be readily located at even remote areas along the transmission system 12 without concern for providing a separate power source (e.g., a storage battery) to the sensing platforms 14. Of course, the arrangement also dispenses with the need to periodically service or replace the storage battery.

Still other advantages are associated with the monitoring system 10. For example, and as shown and described herein, a plurality of individual sensing platforms 14 may be mounted at various locations 16 along the transmission system 12, thereby allowing extended portions, or even substantially the entirety, of the transmission system 12 to be monitored. Alternatively, only selected portions of the transmission system 12 may be monitored with the system 10. In addition, the ability of the sensing platforms 14 to relay transmissions from

adjacent sensing platforms 14 allows low-power transmitters (e.g., transceivers) to be utilized. The signal relaying capability also dispenses with the need to provide more than one endpoint receiver 18, although multiple endpoint receivers 18 may be provided if so desired. In addition, the signals transmitted by the individual sensing platforms 14 are typically of
5 sufficient strength so that they may be received by more than one adjacent sensing platform 14. Consequently, the signal may continue to be relayed even though one of the sensing platforms 14 receiving the transmitted signal may be unable to re-transmit (e.g., relay) the signal.

Moreover, it should also be noted that the various individual sensing platforms 14 and
10 monitoring system 10 are not limited to use with electrical power transmission systems, but could also be used with other types of transmission systems, such as, for example, telecommunications (i.e., telephone) systems, oil pipelines, gas pipelines, water pipelines, or other types of systems for moving or transmitting resources, such as electricity or materials, from one location to another.

15 Having briefly described one embodiment of the methods, apparatus, and systems for monitoring transmission systems, as well as some of their more significant features and advantages, various exemplary embodiments of the invention will now be described in detail.

Referring back now to Figure 1, an exemplary embodiment of a monitoring system 10
is shown and described herein as it may be used to monitor a transmission system 12. The
20 transmission system 12 may comprise an electrical power transmission system 38 having a plurality of electrical conductors 40 supported by a plurality of support towers 42.

Alternatively, the monitoring system 10 may be used with other types of transmission systems, such as, for example, telecommunications (i.e., telephone) systems, oil pipelines, gas

pipelines, water pipelines, or other types of systems for moving or transmitting resources, such as electricity or materials, from one location to another. Consequently, the present invention should not be regarded as limited to use with any particular type of transmission system 12.

5 The monitoring system 10 may comprise at least one, and typically a plurality of sensing platforms 14 provided at various locations 16 along the transmission system 12. For example, in the embodiment shown and described herein wherein the transmission system 12 comprises an electrical power transmission system 38, the various sensing platforms 14 are mounted to one of the electrical conductors 40 at locations 16 nearby the support towers 42.

10 So positioning the various sensing platforms 14 nearby the support towers 42 will allow the sensing platforms 14 to more easily monitor conditions (e.g., event 55) on and around the support towers 42. Of course, other positioning arrangements may be utilized depending on the particular type of transmission system 12 and the conditions to be monitored.

 Before proceeding with the description, it should be noted that the various ones of the

15 sensing platforms 14 comprising the monitoring system 10 may be identical to one another, although this need not be the case. For example, in an alternative embodiment, various ones of the sensing platforms 14 comprising the monitoring system 10 may be provided with different sensing capabilities depending on where they are to be located on the transmission system 12 and depending on the particular condition(s) that is/are desired to be sensed. In

20 addition, various ones of the sensing platforms 14 may include or lack certain other components (e.g., a transmitter 30 or receiver 32), again depending on the particular application as well as the desired sensing and monitoring capabilities of the system 10.

Consequently, the present invention should not be regarded as limited to arrangements wherein the sensing platforms 14 are identical to one another.

Referring now primarily to Figures 2-4, one embodiment of a sensing platform 14 may comprise a housing 24 sized to receive the various components and subsystems of the sensing platform 14. In one embodiment, housing 24 may comprise a two-piece or split housing 24 having a first half 44 and a second half 46. The first and second halves 44 and 46 of split housing 24 may define one or more respective cavities (e.g., 48 and 50) therein sized to receive the various subsystems and components of the sensing platform 14. The first and second halves 44 and 46 may be releasably secured to one another (e.g., via a plurality of fasteners 52) to allow the first and second halves 44 and 46 to be readily separated, thereby providing easy access to the various systems and components housed therein. The two-piece arrangement of housing 24 also allows sensor platform to be readily secured to the electrical conductor 40 of the power transmission system 38.

In addition to housing the various components and subsystems of the sensing platform 14, the housing 24 may also need to be provided with certain other features and attributes to allow it to function well in the intended application (e.g., with the particular type of transmission system 12 involved) and in the expected environment. For example, in an embodiment wherein the sensing platform 14 is to be mounted to an electrical conductor 40 of an electric power transmission system 38, the housing 24 should be configured to minimize the likelihood of corona discharge at the voltages expected in the electrical power transmission system 38. Protection against corona discharge is particularly important wherein the voltages involved are in the tens of kilovolt range or higher. One shape that will minimize corona discharge comprises a generally cylindrically-shaped main body portion 54

having a pair of generally hemispherically-shaped end portions 56, 57, as best seen in Figures 2 and 3. Alternatively, other shapes are possible, as would become apparent to persons having ordinary skill in the art after having become familiar with the teachings provided herein. In order to further reduce the likelihood of corona discharge, any fasteners 52 used to
5 fasten together the two halves 44 and 46 of housing 24 should be recessed within the halves 44 and 46 so that the fasteners 52 do not protrude beyond the exterior surface 58 of housing 24, as best seen in Figure 2.

In such an application, housing 24 should also be made from an electrically conductive material (e.g., aluminum) so that housing 24 will remain at the same electrical
10 potential as the electrical conductor 40. However, suitable precautions also should be taken to prevent the housing 24 from carrying electrical current that would normally be carried by conductor 40. One suitable precaution is to provide an insulator 60 (Figure 3) between one of the ends (e.g., end 56) of housing 24 and the electrical conductor 40, while allowing the other end (e.g., end 57) of housing 24 to remain in electrical contact with conductor 40. Such an
15 arrangement will allow the housing 24 to acquire the electrical potential on conductor 40 while preventing current from flowing through the housing 24 that may otherwise occur due to the “skin effect” associated with electric current flow. Alternatively, other arrangements are possible for achieving these two conditions, as would become apparent to persons having ordinary skill in the art after having become familiar with the teachings provided herein.

20 As mentioned above, the sensing platform 14 may be provided with a variety of subsystems and components in order to carry out the functional and operational aspects of the sensing platform 14. In one embodiment, the various subsystems and components are provided on a single printed wiring board 68 sized to be received within housing 24. Printed

wiring board 68 may be housed within the second or lower half 46 of housing 24. A cover plate 90 may be used to secure the printed wiring board 68 within the second half 46 and to insulate it from conductor 40, as best seen in Figures 2 and 3. Alternatively, other arrangements are possible, as would become apparent to persons having ordinary skill in the art after having become familiar with the teachings provided herein.

Sensing platform 14 may be provided one or more sensors 26 suitable for sensing any of a wide range of conditions of the transmission system 12. In this regard it should be noted that, depending on the particular type of sensor, sensor 26 may be used to sense at least one condition of the transmission system 12 or may be used to sense at least one condition of an environment surrounding the transmission system 12. Exemplary sensors that may be utilized in sensing platform 14 include, but are not limited to, motion sensors (e.g., accelerometers), acoustic sensors, temperature sensors, and optical sensors (e.g., detectors and cameras). However, because the particular type of sensor or sensors 26 that may be utilized may depend on the particular application and conditions to be sensed, the present invention should not be regarded as limited to any particular type of sensor or combinations of sensors. By way of example, in one embodiment, each sensing platform 14 is provided with three sensors 26: A two-axis accelerometer 62, an infra-red detector 64, and a temperature sensor 66. See Figure 3. As mentioned above, the various sensors 26 may be mounted to printed wiring board 68.

Two axis accelerometer 62 detects or senses movement (e.g., acceleration) along two different axes, which may be perpendicular to one another, although this is not required. In addition, the accelerometer 62 should not be regarded as limited to detecting accelerations along two axes, but could instead comprise a single-axis accelerometer, a three-axis

accelerometer, or any combination of single or multi-axis accelerometers, as may be required to sense or detect the desired motion.

In the embodiment shown and described herein, two axis accelerometer 62 may be used to detect motion (e.g., vibrations) of the transmission system 12, such as, for example, vibrations caused by event 55 occurring on or near tower 42. See Figure 1. Two-axis accelerometer 62 may comprise any of a wide range of accelerometers now known in the art or that may be developed in the future that are, or would be, suitable for the intended application. Consequently, the present invention should not be regarded as limited to any particular type of accelerometer. However, by way of example, in one embodiment, the two axis accelerometer 62 comprises an “accelerometer on a chip,” such as, for example product no. ADXL203, available from Analog Devices, Inc., of Norwood, MA. The two-axis accelerometer 62 may be mounted to the printed wiring board 68.

The infra-red detector 64 may be used to detect light in the infra-red portion of the electro-magnetic spectrum. Consequently, infra-red detector 64 may be used to detect objects (e.g., persons, animals, or vehicles) or events that emit infra-red signatures. In one embodiment, infra-red detector 64 comprises a multi-element sensor having a field of view sufficient to encompass the desired area to be sensed. For example, in an embodiment wherein the monitoring system is utilized to monitor an electrical power transmission system 38, it will generally be desirable to provide an infra-red detector 64 having a field of view that is sufficiently large so that detector 64 may be used to monitor a region that includes at least one support tower 42. Consequently, infra-red detector 64 may be used to detect the presence of objects that may pose a threat to the integrity of the support tower 42.

Infra-red detector 64 may comprise any of a wide variety of infra-red detectors that are known in the art or that may be developed in the future. Consequently, the present invention should not be regarded as limited to use with any particular type of infra-red detector 64. However, by way of example, in one embodiment, infra-red detector 64 may comprise an
5 infra-red detector available from PerkinElmer Optoelectronics, Inc., of Fremont, CA as product no. LHi1128. As mentioned above, infra-red detector 64 may be mounted on printed wiring board 68, with a suitable lens 70 mounted to housing 24, as best seen in Figures 2 and 3. Alternatively, other arrangements are possible, as would become apparent to persons having ordinary skill in the art after having become familiar with the teachings provided
10 herein.

Sensing platform 14 may also be provided with a temperature sensor 66 for monitoring an ambient temperature, which may be desirable in certain applications. In one embodiment, temperature sensor 66 may comprise a temperature sensor available from Microchip Technology, Inc., of Chandler, AZ as product no. TC1047. Temperature sensor 66
15 may be mounted on printed wiring board 68, although other arrangements are possible.

The sensing platform 14 may also comprise a control system or processor 28 operatively associated with the sensor or sensors 26. Control system 28 receives output signals 36 from each of the sensors 26 and produces information 20 relating to the one or more conditions sensed by the sensors 26. Control system or processor 28 may also be
20 mounted to printed wiring board 68 and may comprise one or more general-purpose digital signal processors or “computers on a chip” of the type well-known in the art and readily commercially available. By way of example, in one embodiment, the control system 28 comprises two digital signal processors 80 and 82 that operate together to perform the

functions and operations of control system 28. The first digital signal processor 80 operates the various sensors 26, receives the various output signals 36 produced by the sensors 26, and analyzes the output signals 36 to produce information 20 about the sensed conditions. The second signal processor 82 receives the information 20 from the first signal processor 80 and operates the transceiver 34.

The processors 80 and 82 may comprise any of a wide range of processors now known in the art or that may be developed in the future at are, or would be, suitable for the particular application. Consequently, the present invention should not be regarded as limited to any particular type of processor, or even combinations of processors. However, by way of example, in one embodiment, both processors 80 and 82 may comprise processors, available from Microchip Technology, Inc., of Chandler, AZ, as product no. PIC30F6012.

As mentioned above, it is generally desired, but not required, to provide each sensing platform 14 with a transceiver 34 comprising a transmitter 30 and a receiver 32.

Alternatively, a receiver 32 need not be provided, depending on the functionality that is to be provided by sensing platform 14. The transceiver 34 may be connected to a suitable antenna 84 to allow signals (e.g., information 20) to be transmitted by and received from the transceiver 34 as radio-frequency signals. See Figure 1. Transceiver 34 may comprise any of a wide range of transceivers known in the art and that would be suitable for the intended application. Consequently, transceiver 34 should not be regarded as limited to any particular type of transceiver. However, by way of example, in one embodiment, transceiver 34 comprises product no. MICRF505 transceiver available from Micrel, Inc., of San Jose, CA.

Before proceeding with the description, it should be noted that any of a wide variety of alternative configurations and devices may be utilized to transmit the information 20. For

example, the information 20 could be transmitted along one or more components (e.g., electrical conductors 40) of the transmission system 12 itself. Alternatively, the information 20 need not be transmitted by radio, but could instead be transmitted by other means (e.g., by light), as would become apparent to persons having ordinary skill in the art after having
5 become familiar with the teachings provided herein. Consequently, the present invention should not be regarded as limited to the particular types of transmitters (e.g., radio-frequency transmitters) shown and described herein.

Still referring to Figures 2-4, each sensing platform 14 may be provided with a power conversion system 72. Power conversion system 72 allows each sensing platform 14 to be
10 operated by energy derived from the transmission system 12. Power conversion system 72 thereby allows the sensing platform 14 to be operated without the need to provide a separate power source, such as a storage battery. Power conversion system 72 may comprise any of a wide range of systems suitable for deriving energy from the particular type of transmission system 12. Consequently, the present invention should not be regarded as limited to any
15 particular type of power conversion system. However, by way of example, in one embodiment wherein the transmission system 12 comprises an electrical power transmission system 38, power conversion system 72 comprises an inductive power converter 74.

Briefly, inductive power converter 74 may comprise a wire coil 76 (Figure 2) positioned so that it is contained within an alternating magnetic field B produced by the
20 electrical power transmission system 38. In one embodiment, wire coil 76 may be wrapped around a portion of a two-piece or split core element 86 which is configured to surround conductor 40 when the platform 14 is mounted thereto, as best seen in Figures 2 and 3. As is known, the alternating magnetic field B surrounding the conductor 40 will induce an

alternating current flow in wire coil 76. Inductive power converter 74 may also be provided with suitable rectification and regulation circuitry (not shown) to convert the alternating current in wire coil 76 into a regulated, direct current suitable for use by the various components and systems comprising the sensing platform 14.

5 Generally speaking, it will be advantageous to design inductive power converter 74 so that it will be substantially vibration-free during operation, as vibrations produced by inductive power converter 74 would be detected by any accelerometers or motion sensors provided on the sensing platform. Vibration-free operation can be enhanced by ensuring that the core element 86 remains linear (i.e., does not become magnetically saturated) during
10 operation. Inductive power converter 74 may also be provided with one or more large capacitors or “super” capacitors (not shown) to provide electrical power to the sensing platform 14 for some period of time (e.g., minutes) if the current flow in the conductor 40 is lost. Therefore, sensing platform 14 will be able to transmit information about the anomalous condition (e.g., power loss in the conductor 40). Alternatively, other back-up power supplies
15 (e.g., storage batteries) could be utilized.

Referring back now to Figure 1, endpoint receiver 18 may comprise a receiver (not shown) suitable for receiving information 20 transmitted by one or more sensing platforms 14. Endpoint receiver 18 may also be provided with a transmitter (also not shown) for transmitting data to the various sensing platforms 14. In the embodiment shown and
20 described herein, the receiver and transmitter are combined into a transceiver which may be identical to the transceiver utilized in the sensing platforms 14, thus will not be described in further detail herein.

As mentioned, endpoint receiver 18 may be configured to operate in conjunction with user interface system 22. Consequently, endpoint receiver 18 need not be provided with a separate user interface system, although a user interface could be provided directly on endpoint receiver 18. However, endpoint receiver 18 may be provided with a suitable data interface system (also not shown) suitable for allowing endpoint receiver 18 to communicate with user interface system 22. In an example embodiment wherein user interface system 22 comprises a general purpose programmable computer (e.g., a personal computer), the data interface system provided on the endpoint receiver may comprise any of a wide range of data interface systems or communication links 77 suitable for communicating with the particular type of computer comprising the user interface system 22. Consequently, the present invention should not be regarded as limited to any particular type of interface system. However, by way of example, in one embodiment, the data interface system may comprise an RS-232 data interface system.

In this regard it should be noted that alternative variations are possible for allowing endpoint receiver 18 to communicate with user-interface system 22 via communication link 77. For example, in an alternate embodiment, communication link 77 may comprise an existing communication system (e.g., telephone lines, micro-wave relay stations, fiber-optic lines, etc.) located with or nearby the transmission system 12. Thus, information may be transmitted between endpoint receiver 18 and user interface system 22 via the existing communication system. Such an arrangement may allow one or more endpoint receivers 18 to be conveniently mounted on one or more support towers 42 (Figure 1) and tied-in to the existing communication system (e.g. telephone line), thereby allowing the user interface system 22 to be provided at any convenient location.

Still referring to Figure 1, user interface system 22 may comprise any of a wide range of systems and devices known in the art or that may be developed in the future that are or would be suitable for allowing the desired degree of user interface with monitoring system 10. In the embodiment shown and described herein, the user interface system 22 may
5 comprise a general purpose programmable computer system, such as a personal computer having a display 78 and a keyboard 88. Information 20 received by endpoint receiver 18 may be displayed on display 78 of user interface 22. The keyboard 88 may be utilized to manipulate the information 20 and/or change the layout of the information 20 provided on display system 78. In addition, and as will be described in greater detail below, user interface
10 system 22 may be used to send data and/or programming information or modifications back to the sensing platforms 14 via the transceiver provided in the endpoint receiver 18.

The monitoring system 10 may be operated as follows to sense at least one condition of the transmission system 12. As was previously described, the various sensing platforms 14 may be used to sense one or more conditions of the transmission system 12, ranging from, for
15 example, vibrations of the transmission system 12 sensed by the accelerometer 62, infra-red light emitted by objects or persons within the sensing area of infra-red sensor 64, and/or the ambient temperature, as sensed by the temperature sensor 66. The output signal(s) 36 from the sensor or sensors 26 are received by the control system or processor 28. While the control system or processor 28 may simply pass-on the signals to the transmitter 30 without
20 evaluation or analysis (whereupon they may be transmitted as information 20), it will generally be more preferable for the control system or processor 28 to first evaluate or analyze the output signals 36 in order to determine whether the sensed conditions are normal

or anomalous. In this way, only information 20 that relates to an anomalous condition need be transmitted.

A data processing routine 92 that may be utilized by the control system 28 to evaluate the output signals 36 is illustrated in Figure 5. In one embodiment, the output signal 36 from the sensors 26 may be pre-filtered at step 94 in order to remove unwanted or undesirable components (e.g., 60 Hz noise and harmonics thereof) from the output signals 36 in order to simplify subsequent processing and analysis. The pre-filtering process 94 may involve the use of one or more analog or digital filters, such as high-pass, low-pass, or band-pass filters. The particular characteristics of the pre-filter 94 may vary depending on the particular types of output signals 36 produced by the various sensors 26 and would be easily selected by persons having ordinary skill in the art after having become familiar with the teachings provided herein and after considering the particular sensors 26 to be utilized and noise components to be removed. Consequently, the particular types of filters that may be utilized in the pre-filtering process 94 will not be described in further detail herein.

After suitable pre-filtering, filtered signals may then be digitized at step 96. Of course, such digitization need not be performed if the signals already comprise digital, as opposed to analog, signals. The digitized signals may then be processed by any of a wide variety of digital signal processing techniques in order to produce signals that may be more conducive to the subsequent analysis process 104. The particular digital signal processing techniques will depend on the type of analysis to be performed, i.e., to determine whether the signals 36 are indicative of a normal condition or an anomalous condition, as well as on the particular nature of the output signals, e.g., whether the output signals 36 were generated by an accelerometer (e.g. 62), an infra-red sensor (e.g., 64), or by a temperature sensor (e.g., 66).

For example, an output signal from a temperature sensor (e.g., 66) will require much less processing than an output signal generated by an accelerometer (e.g. 62) or an infra-red sensor (e.g., 64), in order to determine whether the signal is regarded as indicative of a normal condition or an anomalous condition. Consequently, the present invention should not be regarded as limited to any particular digital signal processing technique or series of signal processing techniques. However, by way of example, in one embodiment, a subsequent digital signal processing technique may comprise a fast Fourier transfer (FFT) step 98, in which the output signals are converted from the time domain into the frequency domain. A subsequent filtering step 102 may then be conducted to filter or remove unwanted components from the processed signal.

After the output signals 36 have been digitized, processed, and filtered, as described above, they may then be analyzed at step 104. As mentioned above, the analysis process 104 may be performed to determine whether the output signal 36 produced by the sensor 26 is indicative of a normal condition or an anomalous condition. One way to make such a determination is to compare the output signal with a threshold value or values associated with a normal condition. If the output signal is outside the threshold value or values, then the sensed condition is regarded as anomalous. The particular threshold value or values that may be utilized will depend on the particular sensor output signal to be analyzed as well as on the particular type of transmission system 12 and environment. In certain circumstances, it will be sufficient to simply compare the processed output signal with the corresponding threshold value or values established for the particular sensor. However, in other cases, it may be necessary to additional process the data before making the comparison.

For example, and with reference now to Figure 6, a better determination as to whether data from a motion sensor (e.g., accelerometers 62) are indicative of a normal condition or an anomalous condition may require the power spectrum of the signal to be computed, as illustrated in step 106. The impulse energy of the power spectrum may then be computed at step 108. The computed impulse energy may then be compared with a corresponding threshold value or values at step 110.

Before proceeding with the description, it should be noted that the threshold value or values may be developed from testing associated with the particular type of transmission system 12, as well as on the particular type of sensor. For example, in the case of sensing vibrations of an electrical power transmission system 38 that may be caused by a potentially threatening event 55 (e.g., an explosion, sawing, hammering, or climbing) on one or more support towers 42, suitable threshold values may be determined by measuring accelerations detected by one or more sensing platforms 14 mounted on the electrical conductors 40 in response to simulated events. The resulting responses may then be used to establish corresponding threshold values.

While the accelerations themselves could be analyzed (i.e., as they are detected in the time domain), it will generally be easier to perform the analysis if the acceleration data is converted into the frequency domain (e.g., via fast-Fourier transform process 98, Figure 5). The power spectrum and impulse energy can be calculated (at steps 106 and 108, respectively) by known techniques. In this way, threshold values associated with potentially threatening activities can be determined and programmed into the control system 28 (Figure 4). Then, if similar signals are detected (e.g., as determined in step 110), then a determination can be made at step 112 as to whether the signals are indicative of a normal condition (e.g.,

vibrations due to wind) or an anomalous condition (e.g., sawing or hammering occurring on one or more support towers 42). If an anomalous condition is determined, the control system 28 may then operate transmitter 30 to transmit information 20 relating to the anomalous condition. That is, the analysis process 104 can report the anomalous condition at step 114.

5 The analysis process 104 may also be configured to send a report (i.e., transmit information 20) when the condition clears at step 116.

As mentioned, the information 20 provided in the report (e.g., at step 114) transmitted by the sensing platform 14 may comprise any of a wide range of information. For example, in addition to merely reporting the detection of an anomalous condition, information 20 may
10 contain processed data (e.g., the calculated impulse energy), as well as unprocessed or raw data produced by the sensors 26. The information 20 may also include data from other sensors 26 even if the data produced thereby was determined to be indicative of a normal condition. Of course, the information 20 may also contain the identity and/or location of the sensing platform 14 that detected the anomalous condition. In short, information 20 may
15 comprise any of a wide variety of information that may be useful to a system operator if an anomalous condition is detected.

The information 20 transmitted by the sensing platform 14 that detected the anomalous condition may be relayed by one or more other sensing platforms 14 provided on the transmission system 12 before being received by endpoint receiver 18, as already described. Endpoint receiver 18 may operate in conjunction with user interface 22 in order to
5 provide the information 20 in any desired form. For example, upon initial receipt of information 20 relating to an anomalous condition, user interface 22 may be programmed to provide a visual and/or aural alarm. The identification and location of the particular sensing

platform or platforms 14 that detected the anomalous condition may also be provided, along with processed data and/or raw data. Any other information may be provided that would be deemed useful to a system operator in evaluating the seriousness of the situation. For example, if the sensing platform 14 is provided with an optical sensor (e.g., a camera), image data from the camera may be provided to allow a user to perhaps determine the cause of the anomalous condition.

As described earlier, the user interface 22 and endpoint receiver 18 may also be used to transmit information to the various sensing platforms 14. For example, in response to receiving information 20 indicative of the detection of an anomalous condition, the user may instruct the user interface 22 to send a signal to the sensing platform 14 requesting additional data relating to the detected condition. The user interface 22 could also be used to re-program one or more of the other sensing platforms 14 to, for example, change the threshold levels. Such re-programming could allow the anomalous condition to be determined with more certainty by determining whether other sensing platforms 14 detected similar data. Of course, such re-programming of the sensing platforms 14 need not be done upon the detection of an anomalous condition, but could be done at any time. Many other variations are possible, as would become apparent to persons having ordinary skill in the art after having become familiar with the teachings provided herein. Consequently, the present invention should not be regarded as limited to the particular programming sequences and operational scenarios shown and described herein.

Having herein set forth preferred embodiments of the present invention, it is anticipated that suitable modifications can be made thereto which will nonetheless remain

within the scope of the invention. The invention shall therefore only be construed in accordance with the following claims:

CLAIMS:

1. A sensing platform for monitoring a transmission system, comprising:
a sensor, said sensor sensing one or more conditions selected from the group consisting essentially of:
a condition of the transmission system; and
a condition of an environment around the transmission system,
said sensor producing an output signal related to the sensed condition;
a control system operatively associated with said sensor and responsive to the output signal produced by said sensor, said control system producing output data based on the output signal produced by said sensor; and
a transmitter operatively associated with said control system, said transmitter transmitting the output data from said control system.
2. The sensing platform of claim 1, wherein said sensor comprises one or more selected from the group consisting essentially of an accelerometer, an acoustic sensor, an optical sensor, and a temperature sensor.
3. The sensing platform of claim 2, wherein said accelerometer comprises a two-axis accelerometer.
4. The sensing platform of claim 2, wherein said optical sensor comprises an infra-red detector.

5. The sensing platform of claim 1, wherein said transmitter comprises a radio-frequency transmitter.

6. The sensing platform of claim 1, further comprising a power converter operatively associated with the transmission system, said power converter extracting energy from the transmission system and converting the extracted energy into a form useable by said sensing platform.

7. The sensing platform of claim 6, wherein the transmission system comprises an electrical power transmission system and wherein said power converter comprises an inductive converter.

8. The sensing platform of claim 1, further comprising a receiver, said receiver receiving transmitted signals from another sensing platform.

9. The sensing platform of claim 8, wherein said receiver and said transmitter comprise a transceiver.

10. A system for monitoring a transmission system, comprising:
a plurality of sensing platforms operatively associated with the transmission system at a corresponding plurality of locations along the transmission system, each of said plurality of sensing platforms comprising:

a sensor, said sensor sensing one or more conditions selected from the group consisting essentially of:

a condition of the transmission system; and

a condition of an environment around the transmission system, said sensor producing an output signal related to the at least one condition sensed;

a control system operatively associated with said sensor and responsive to the output signal produced by said sensor, said control system producing output data based on the output signal produced by said sensor; and

a transceiver operatively associated with said control system, said transceiver transmitting the output data from said control system; and at least one endpoint receiver, said at least one endpoint receiver receiving output data transmitted by said at least one of said plurality of sensing platforms.

11. The system of claim 10, further comprising a user-interface system operatively associated with said at least one endpoint receiver.

12. A method for monitoring a transmission system, comprising:
sensing one or more conditions selected from the group consisting essentially of:

a condition of the transmission system; and

a condition of an environment around the transmission system; and transmitting data related to the sensed condition.

13. The method of claim 12, further comprising:
determining whether said sensed condition is a normal condition or an anomalous condition; and
transmitting information about the anomalous condition when the anomalous condition is determined.
14. The method of claim 12, further comprising:
receiving the transmitted data related to the sensed condition at an intermediate transceiver;
re-transmitting data related to the sensed condition; and
receiving the re-transmitted data at an endpoint receiver.
15. The method of claim 12, wherein transmitting data related to the sensed condition comprises transmitting radio frequency signals.
16. The method of claim 12, wherein the transmission system comprises a power transmission system having power lines and wherein transmitting comprises transmitting via the power lines.
17. A sensing platform, comprising:
sensor means for sensing one or more conditions selected from the group consisting essentially of:
a condition of a transmission system; and

a condition of an environment around the transmission system,
and for producing an output signal related to the sensed condition;

means, operatively associated with said sensor means, for operating said
sensor means and for processing the output signal from said sensor means to produce
output data; and

means for transmitting the output data.

1/5

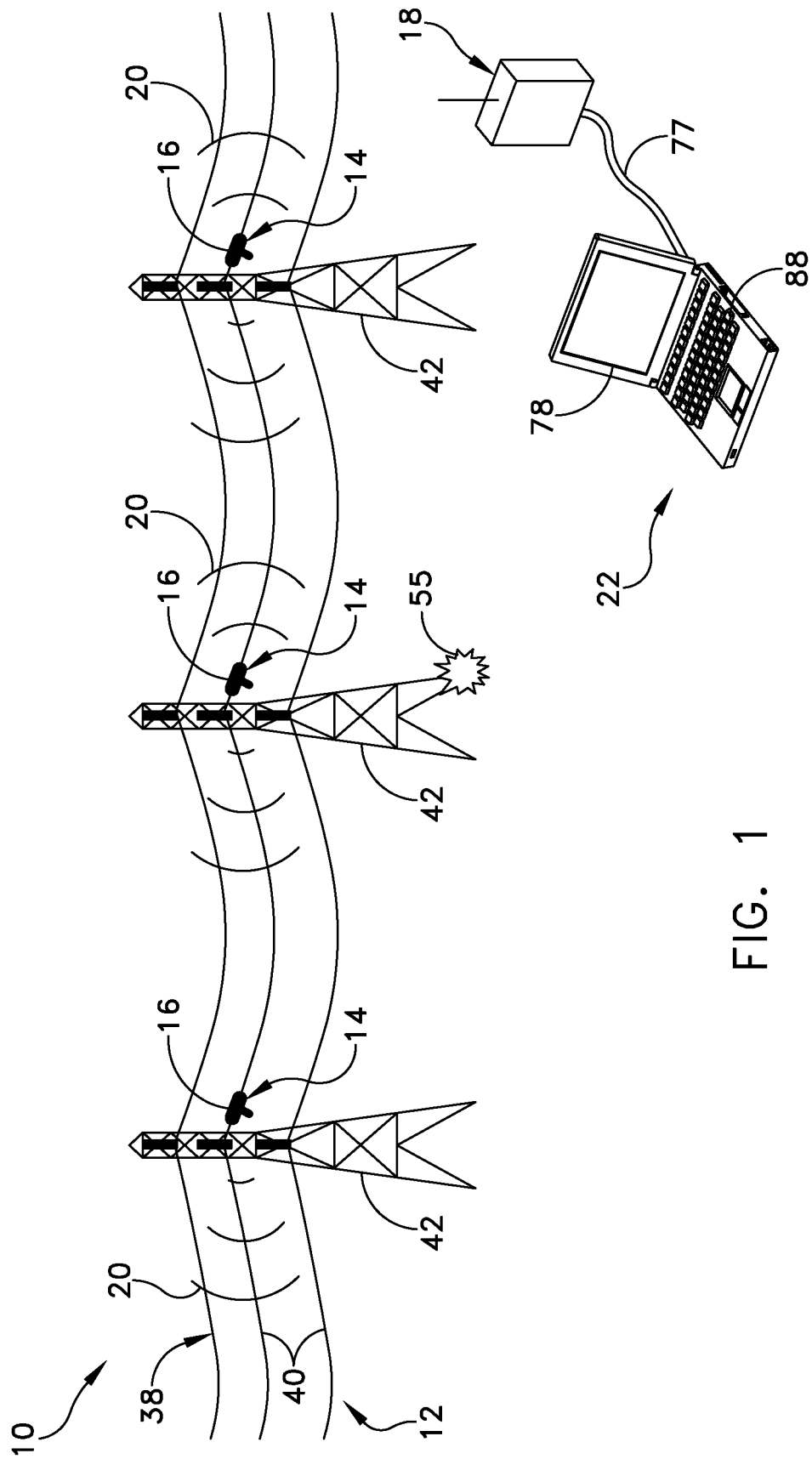


FIG. 1

2/5

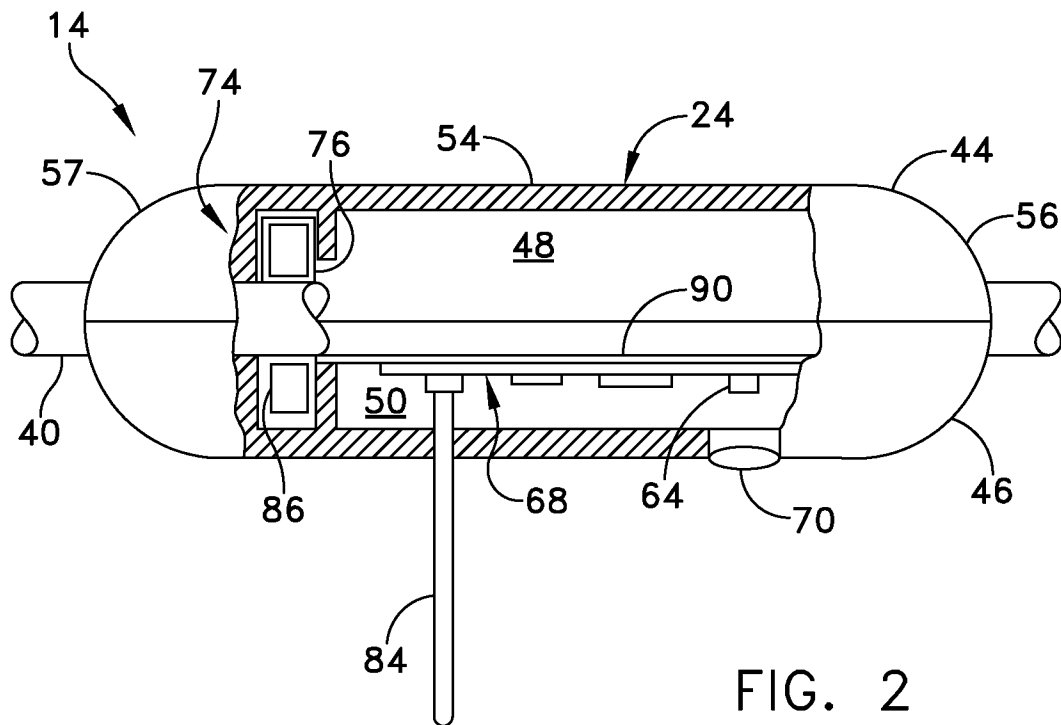


FIG. 2

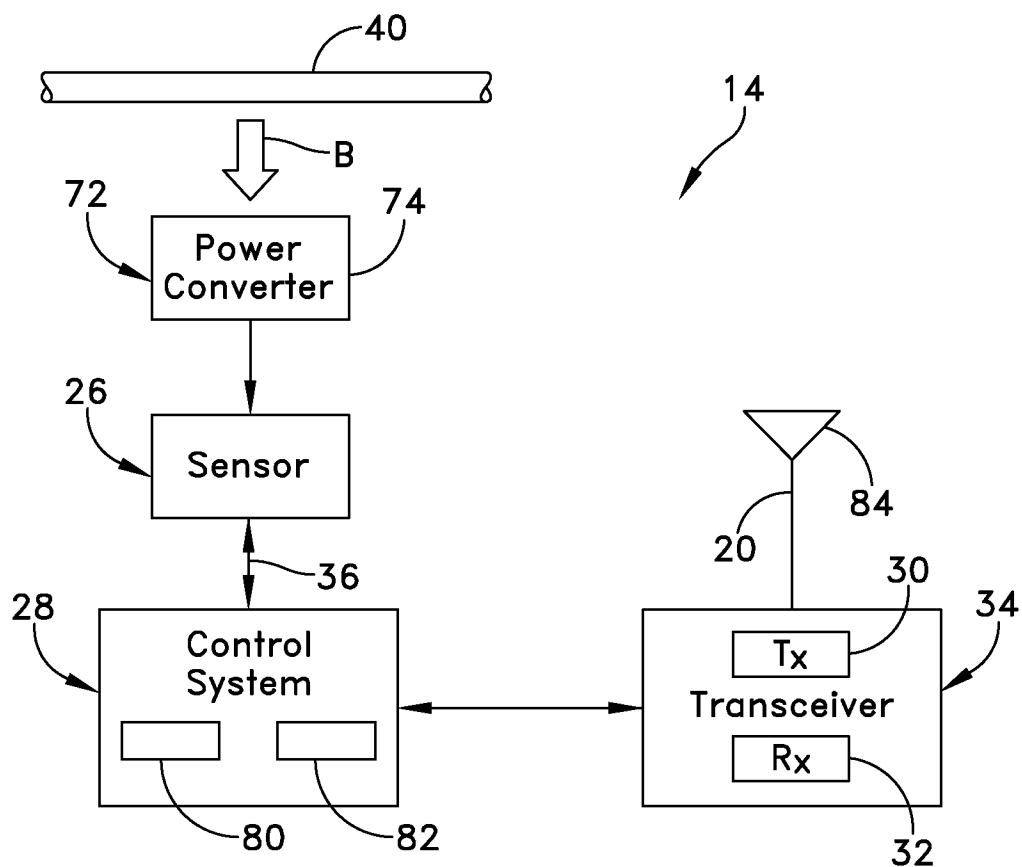


FIG. 4

3/5

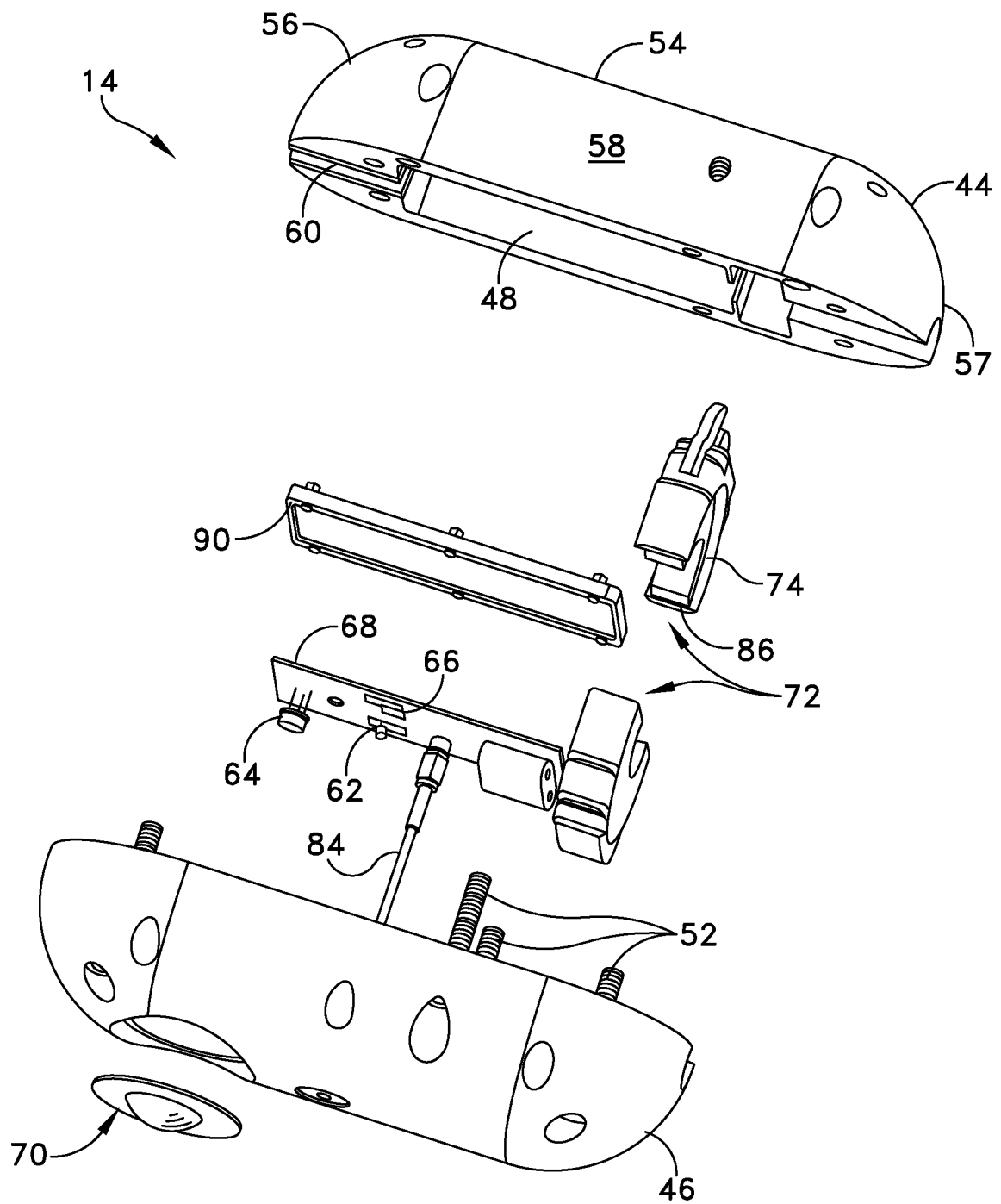


FIG. 3

4/5

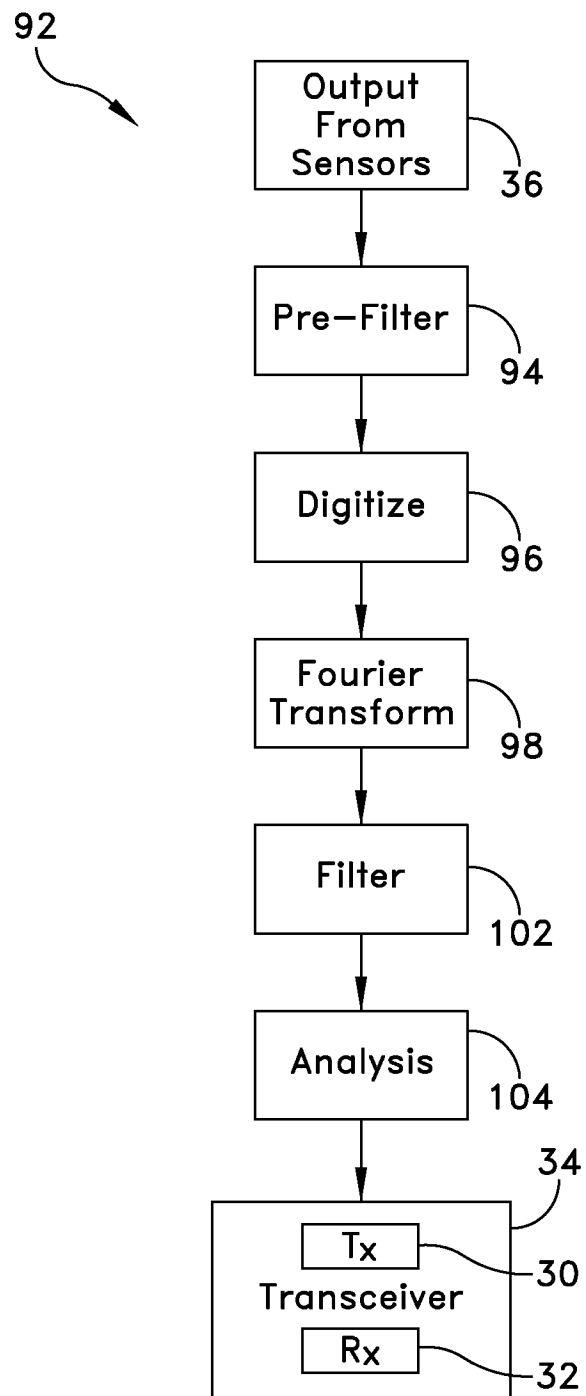


FIG. 5

5/5

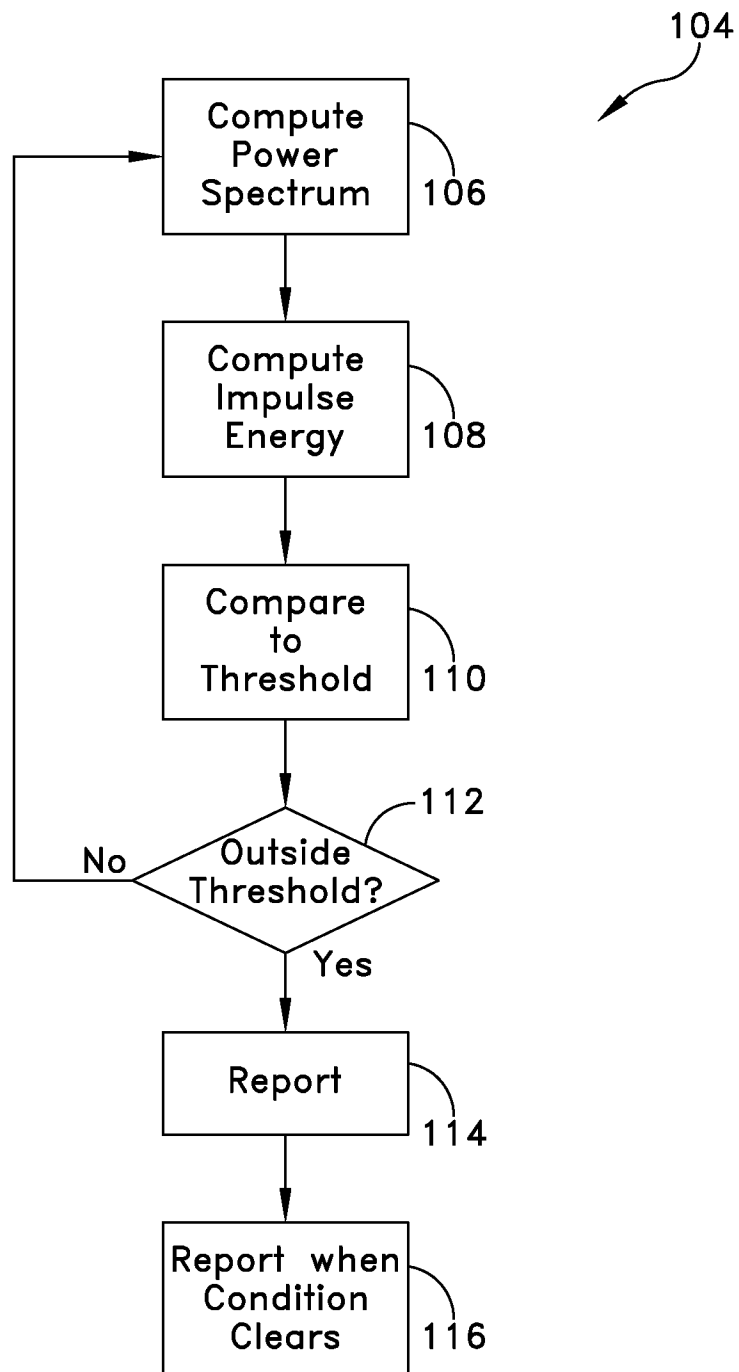


FIG. 6