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READER IN AN ELECTRONIC TOLL
COLLECTION SYSTEM****Publication Classification**(51) **Int. Cl.****H04Q 5/22** (2006.01)(52) **U.S. Cl.** **340/10.2; 340/928; 235/384;
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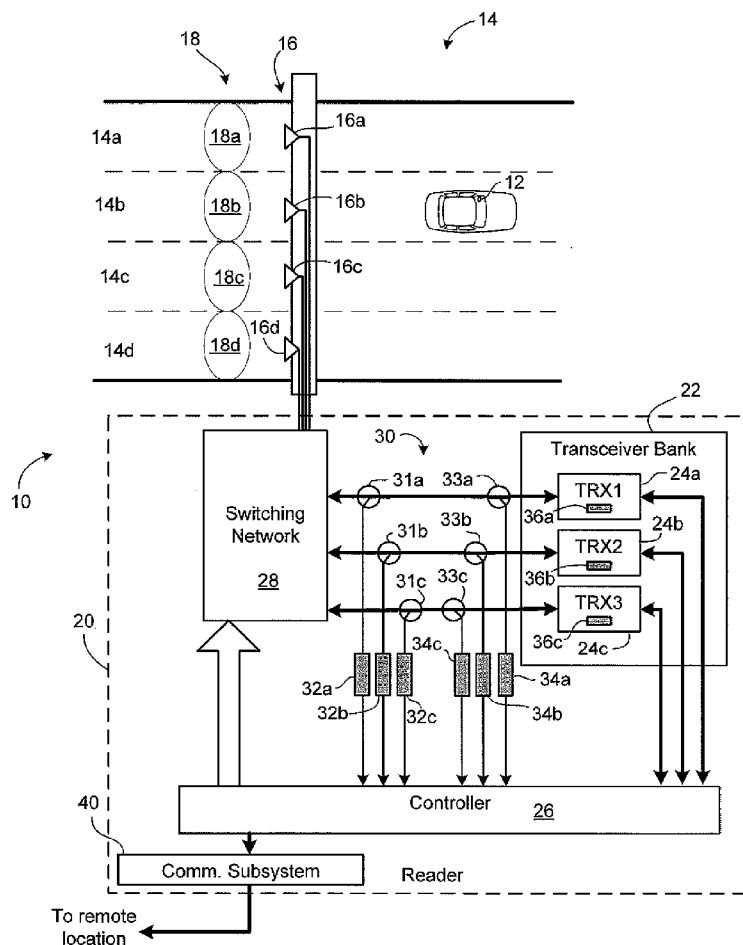
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21, 2005. Provisional application No. 60/718,743,
filed on Sep. 21, 2005. Provisional application No.
60/718,744, filed on Sep. 21, 2005.

(57)

ABSTRACT

An electronic toll collection system that includes a reader with internal monitoring circuitry. The reader includes a controller and transceiver, which is connected to an antenna, wherein the transceiver sends outgoing RF signals to the antenna and receives incoming RF signals from the antenna. The reader includes transceiver monitor circuitry for monitoring the characteristics of the RF signals to assess transceiver performance. The transceiver monitor circuitry provides a result signal to the controller. The controller may adjust the operation of the transceiver through adjustments to an adjustable element based upon the measurement signals. The controller may also send measurement information to a remote computer and receive instructions from the remote computer, thereby enabling remote monitoring and adjustment of the electronic toll collection system.



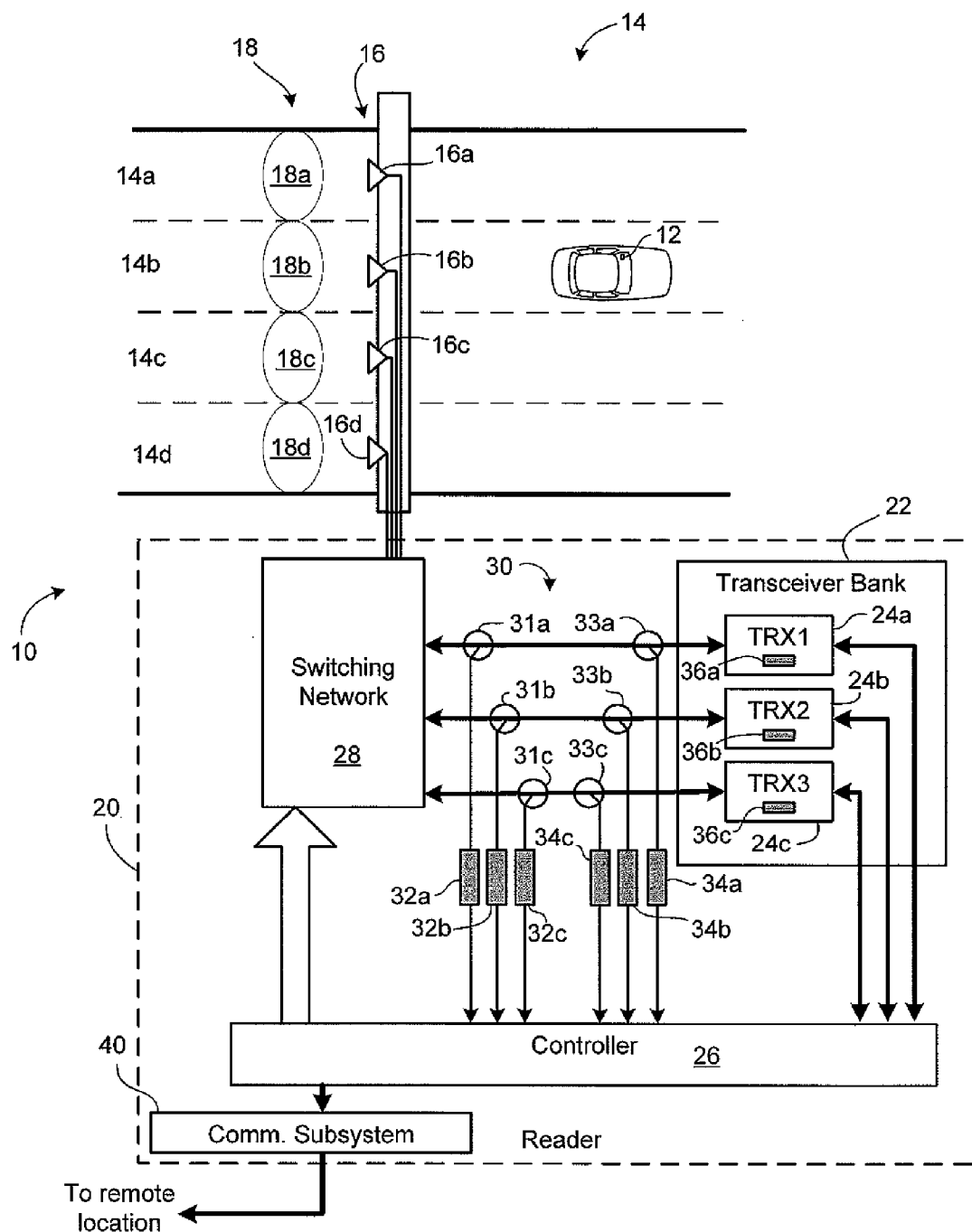


FIG. 1

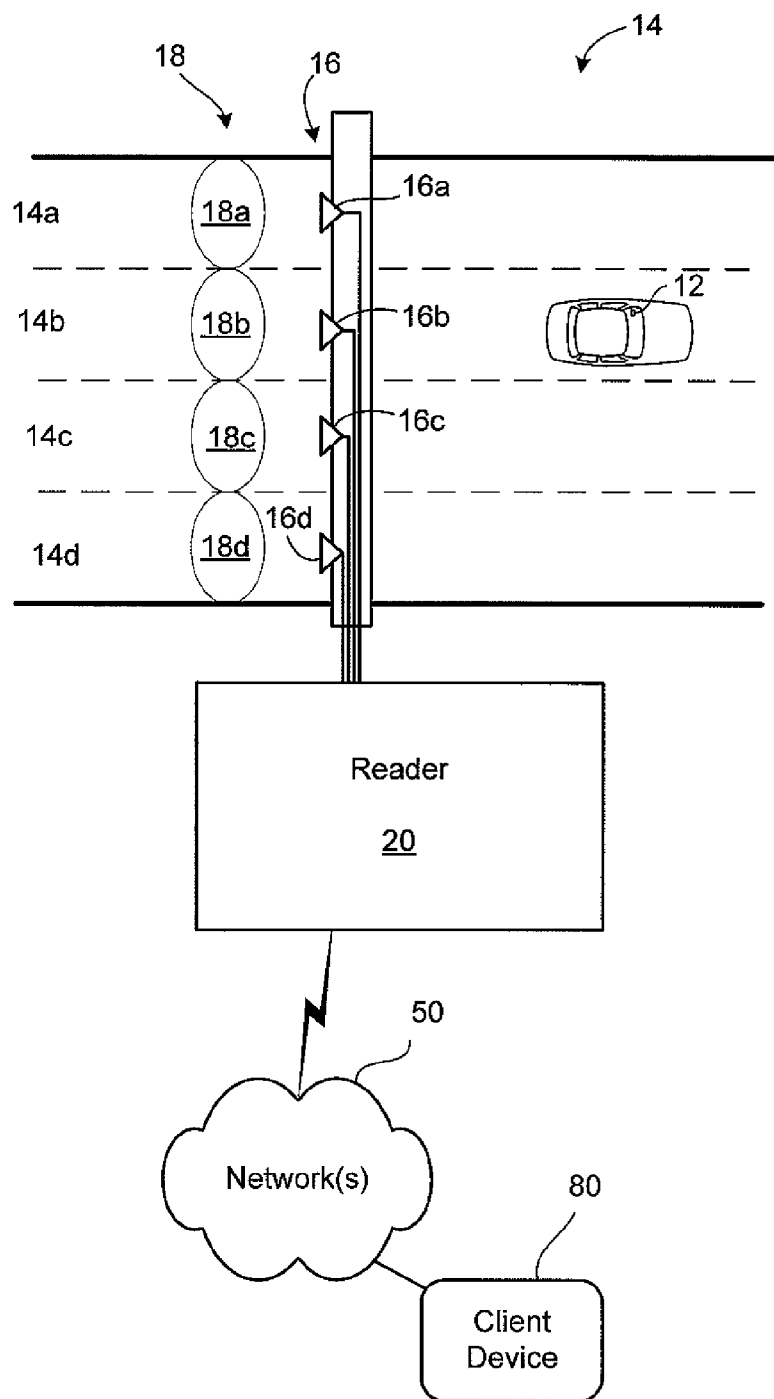


FIG. 2

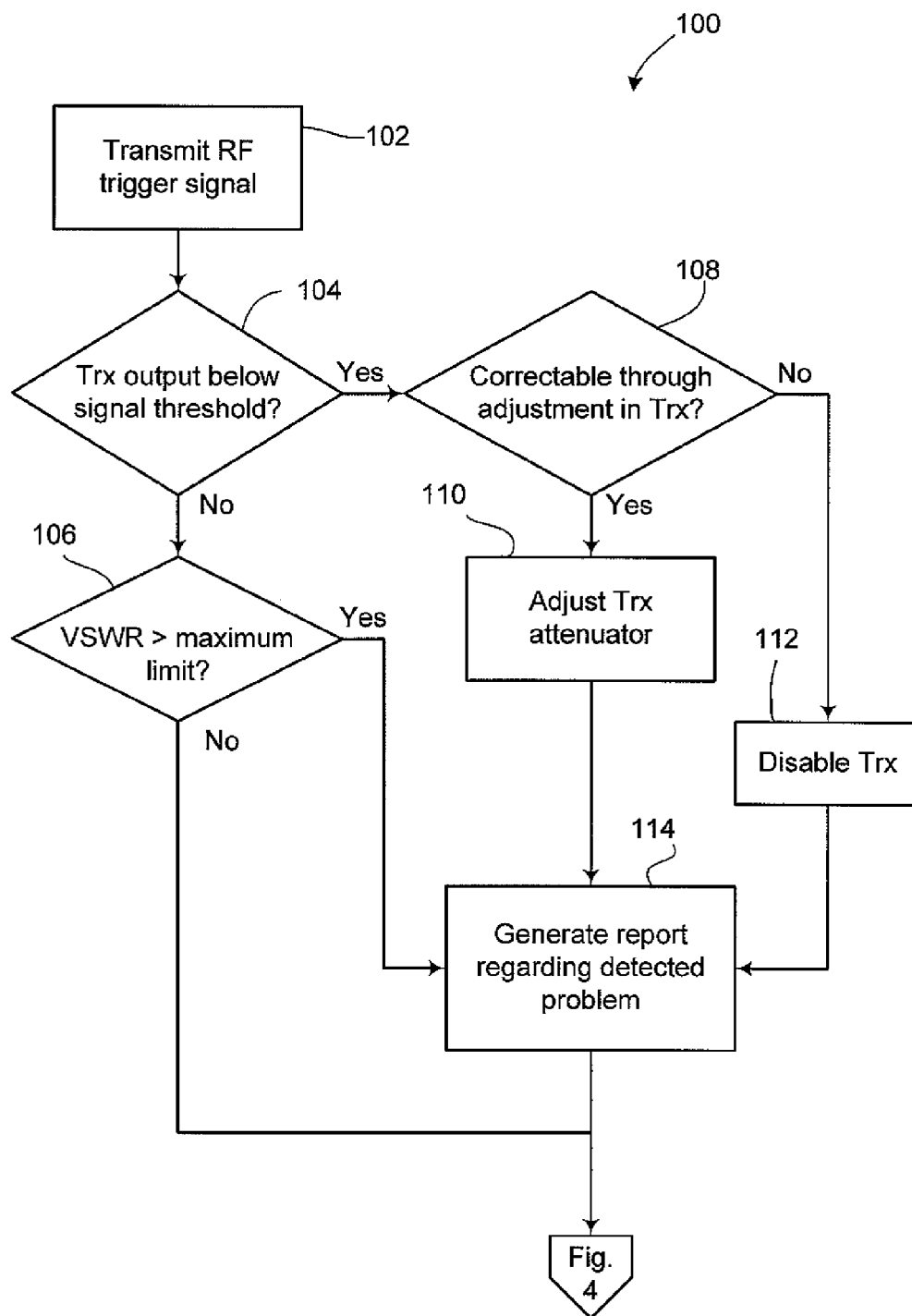


FIG. 3

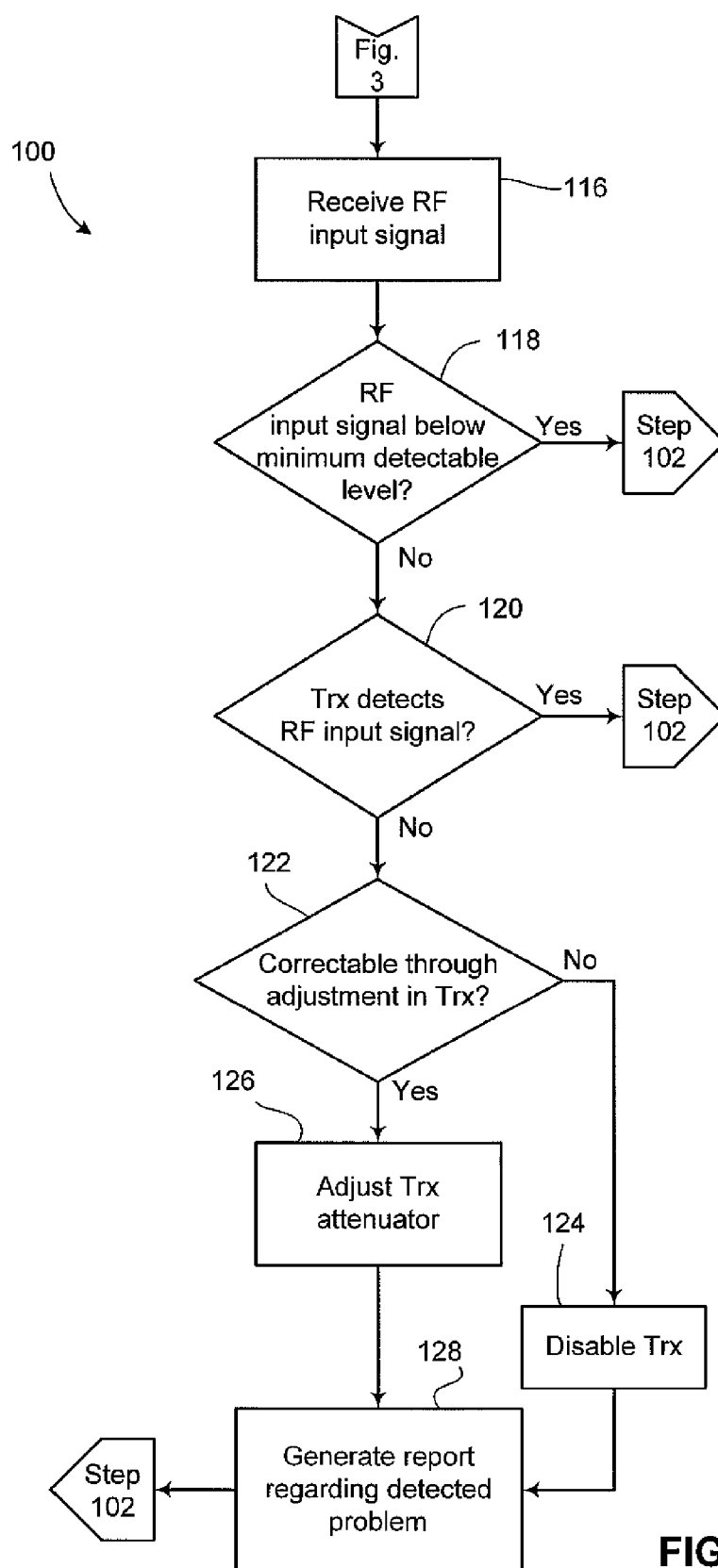


FIG. 4

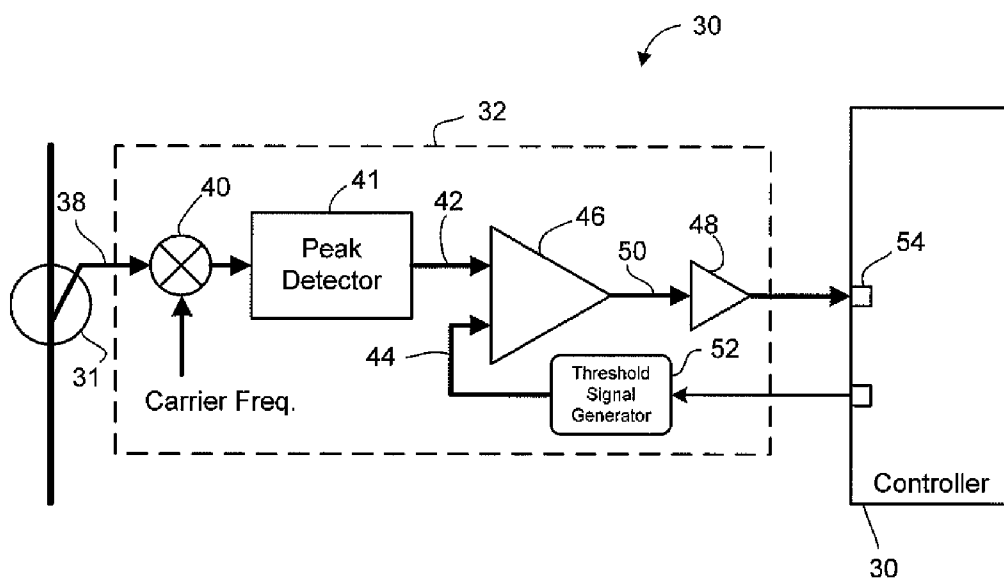


FIG. 5

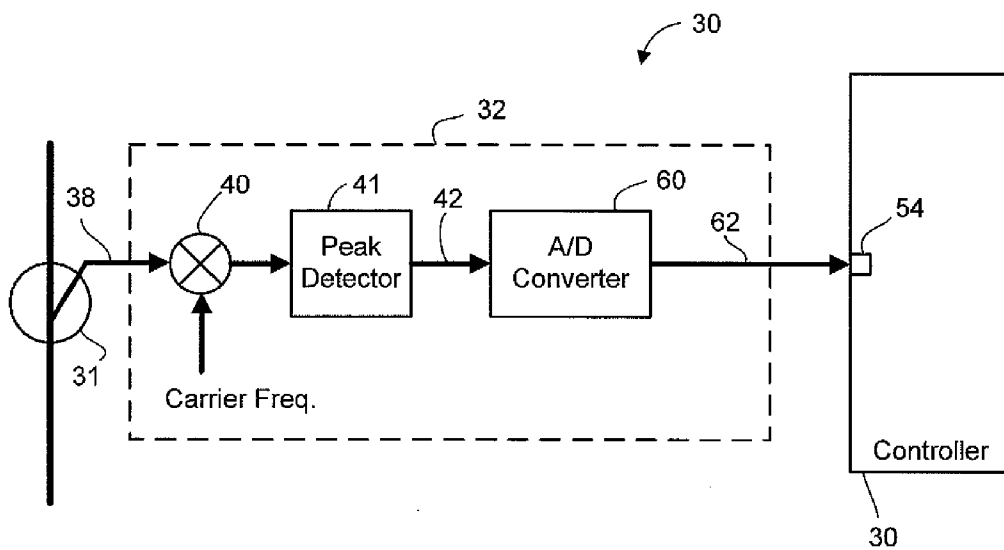


FIG. 6

MONITORING AND ADJUSTMENT OF READER IN AN ELECTRONIC TOLL COLLECTION SYSTEM

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] The present application claims priority to U.S. provisional patent application Ser. No. 60/718,742, U.S. provisional patent application Ser. No. 60/718,743, and U.S. provisional patent application Ser. No. 60/718,744, all filed Sep. 21, 2005.

FIELD OF THE INVENTION

[0002] The present invention relates to electronic toll collection systems and, in particular, an electronic toll collection system with monitoring and adjustment of a reader.

BACKGROUND OF THE INVENTION

[0003] Electronic toll collection systems conduct toll transactions electronically using RF communications between a vehicle-mounted transponder (a "tag") and a stationary toll plaza transceiver (a "reader"). An example of an electronic toll collection system is described in U.S. Pat. No. 6,661,352 issued Dec. 9, 2003 to Tiernay et al., and owned in common with the present application. The contents of U.S. Pat. No. 6,661,352 are hereby incorporated by reference.

[0004] In a typical electronic toll collection (ETC) system, a set of antennas are disposed to cover the roadway with overlapping coverage zones. Each antenna broadcasts a wakeup or trigger RF signal within its coverage zone. A tag on a vehicle passing through the coverage area or zone detects the wakeup or trigger signal and responds with its own RF signal. The tag responds by sending a response signal containing information stored in memory in the transponder, such as the transponder ID number. The response signal is received by the antenna.

[0005] The antennas operate under the control of a reader that typically uses time multiplexing to scan the roadway for transponders using each antenna in turn. When an antenna receives a response signal, the response signal is input to the reader, which may then conduct an electronic toll transaction, such as by debiting a user account associated with the transponder ID number. The reader may then cause the antenna to broadcast a programming RF signal to the tag. The programming signal provides the tag with updated information for storage in its memory. It may, for example, provide the tag with a new account balance.

[0006] In one electronic toll collection system, the reader may include one or more RF transceivers and a controller. The controller controls operation of the RF transceiver(s) and conducts the toll transactions. The controller may cause a multiplexer to selectively connect the RF transceiver to each of the antennas, thereby implementing time multiplexed scanning. In some cases one or more of the transceivers may fail or may experience degradation in signal power. The possible reasons for this are numerous, but the effect is that the radiated power from one or more of the antennas is reduced, which can result in missed transactions. In some cases, the receiver portion of the transceiver

degrades or fails. In yet other cases, the transmission line between the transceiver and the antenna degrades or is damaged. In yet other cases, the antenna degrades or is damaged. These situations can give rise to a mismatch in impedance, increased path resistance, and/or worse signal-to-noise performance.

[0007] The result of these problems may be a loss in output power and/or in received power. These conditions can be difficult to detect and may persist for long periods of time without being noticed or repaired.

[0008] It would be advantageous to have an improved electronic toll collection system.

SUMMARY OF THE INVENTION

[0009] The present invention provides an electronic toll collection system that including internal monitoring circuitry. A reader includes a controller and transceiver, which is connected to an antenna, wherein the transceiver sends outgoing RF signals to the antenna and receives incoming RF signals from the antenna. The reader includes transceiver monitor circuitry for monitoring the characteristics of the RF signals to assess transceiver performance. The transceiver monitor circuitry provides a measurement signal to the controller. The controller may adjust the operation of the transceiver through adjustments to a digital attenuator based upon the measurement signals. The controller may also send measurement information to a remote computer and receive instructions from the remote computer, thereby enabling remote monitoring and adjustment of the electronic toll collection system.

[0010] In one aspect, the present application provides an electronic toll collection system for conducting toll transactions with vehicle-mounted transponders travelling in a roadway. The electronic toll collection system includes at least one antenna having a coverage area for exchanging RF communications with a transponder in the roadway, and a reader connected to the at least one antenna. The reader includes a transceiver having an RF port for exciting the at least one antenna with an RF output signal and for receiving RF input signals induced in the at least one antenna by the transponder, and the transceiver includes an adjustable element having a setting responsive to an adjustment signal. The reader also includes a controller for controlling the transceiver and for outputting the adjustment signal, and a transceiver monitor circuit connected to the RF port for measuring characteristics of the RF output signal and the RF input signal, the transceiver monitor circuit providing a result signal to the controller. The controller is configured to generate the adjustment signal based upon the result signal.

[0011] In another aspect, the present application provides a method of monitoring operation of an electronic toll collection system for conducting toll transactions with vehicle-mounted transponders travelling in a roadway. The ETC system includes at least one antenna having a coverage area for exchanging RF communications with a transponder in the roadway and a reader connected to the at least one antenna. The reader includes a transceiver having an RF port for exciting the at least one antenna with an RF output signal and for receiving RF input signals induced in the at least one antenna by the transponder, and the transceiver includes an adjustable element having a setting responsive to an adjustment signal. The reader also includes a controller for con-

trolling the transceiver and for outputting the adjustment signal. The method includes steps of measuring characteristics of the RF output signal and the RF input signal, calculating an adjustment based upon the measured characteristics, and generating the adjustment signal to implement the calculated adjustment.

[0012] Other aspects and features of the present invention will be apparent to those of ordinary skill in the art from a review of the following detailed description when considered in conjunction with the drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0013] Reference will now be made, by way of example, to the accompanying drawings which show an embodiment of the present invention, and in which:

[0014] FIG. 1 shows a block diagram of an embodiment of an electronic toll collection (ETC) system.

[0015] FIG. 2 shows another block diagram of the ETC system shown in FIG. 1.

[0016] FIGS. 3 and 4 show, in flowchart form, a method for monitoring and adjusting transceivers in the ETC system.

[0017] FIG. 5 diagrammatically shows an example embodiment of a portion of the transceiver monitor circuitry within the reader of the ETC system.

[0018] FIG. 6 diagrammatically shows another example embodiment of a portion of the transceiver monitor circuitry within the reader.

[0019] Similar reference numerals are used in different figures to denote similar components.

DESCRIPTION OF SPECIFIC EMBODIMENTS

[0020] Reference is first made to FIG. 1, which shows a block diagram of an embodiment of an electronic toll collection system 10. The system 10 operates to send and receive RF communications with vehicle-borne transponders 12. In one embodiment, the system 10 is associated with a gated toll plaza. In another embodiment, the system 10 is associated with an open-road toll processing zone. Other applications for the system 10 will be appreciated by those skilled in the art.

[0021] In the embodiment shown in FIG. 1, the system 10 is associated with a multi-lane roadway 14. Individual lanes are shown as lanes 14a, 14b, 14c, and 14d.

[0022] The system 10 includes a set of antennas 16 (shown individually as 16a, 16b, 16c, and 16d). FIG. 1 shows that each antenna 16 is associated with a laneway. In particular, each antenna 16 is a directional antenna having a beam path that defines an antenna-specific capture zone 18 within the roadway 14. The antennas 16 may, in some embodiments, be mounted to an overhead gantry or other structure. In many embodiments, the antennas 16 may be positioned such that their respective capture zones 18 span the width of the roadway 14 to ensure total coverage of all lanes of traffic.

[0023] It will be appreciated that there may be more antennas 16 or fewer antennas 16 than lanes in the roadway 14. In one embodiment, midpoint or mid-lane antennas are also deployed defining a capture zone roughly centered at

the midpoint between lanes. The mid-lane antennas provide overlapping coverage with the center-lane antennas 16 and may be useful in determining lane position of a transponder 12 within the roadway 14. Other configurations of the antennas 16 will be appreciated by those skilled in the art.

[0024] The antennas 16 are connected to a roadside reader 20. The roadside reader 20 excites each antenna 16 so as to induce propagation of an RF signal in the associated capture zone 18. The antenna 16 receives incoming RF signals, which are input to the reader 30. The incoming RF signals include transmissions from any active transponders within the capture zone 18. It will be appreciated that the electronic toll collection system 10 may be based upon one or more pre-defined communications protocols and may involve the use of active or backscatter transponders.

[0025] The pre-defined communications protocols used in the system 10 include propagation of a trigger signal or wake-up signal by the antennas 16 in their respective capture zones 18. Any transponder 12 within a particular capture zone 18 may respond by transmitting a response signal, which is received by the antenna 16 and input to the reader 20.

[0026] In many embodiments, the reader 20 employs a time multiplexed scan, whereby each antenna 16 is assigned a time slot within which the antenna 16 broadcasts its trigger signal and awaits a response, if any. In the embodiment depicted in FIG. 1, the protocol may provide for four time slots during which each antenna is sequentially used to poll for transponders 12 in its respective capture zone 18.

[0027] The roadside reader 20 includes a transceiver bank 22 and a controller 26. The transceiver bank 22 contains transceivers 24. The transceivers 24 are configured to modulate signals from the controller 26 for transmission as RF signals over the antennas 16, and to de-modulate RF signals received by the antennas 16 into a form suitable for use by the controller 26. In this regard, the reader 20 employs hardware and signal processing techniques that will be well understood by those skilled in the art. The controller 26 may include a programmable processing unit, volatile and non-volatile memory storing instructions and data necessary for the operation of the controller 26, and communications interfaces to permit the controller 26 to communicate with the transceivers 24.

[0028] In some embodiments, the transceiver bank 22 may include a dedicated transceiver 24 for each antenna 16. In some embodiments, the transceiver bank 22 may include a single transceiver 24 that is used for each antenna 16. In other embodiments, the transceiver bank 22 may include some operative transceivers and some redundant transceivers as described in U.S. provisional patent application Ser. No. 60/718,742 filed Sep. 21, 2005 and owned in common herewith, the contents of which are hereby incorporated by reference.

[0029] The reader 20 further includes a switching network 28 for selectively connecting one of the transceivers 24a, 24b, and 24n, with one of the antennas 16. In some embodiments, the switching network 28 may only connect one transceiver 24 to one antenna 16 at any given time; however, in other embodiments, the switching network 28 may allow for connections between more than one antenna 16 and respective transceivers 16. For example, the switching net-

work **28** may contemporaneously connect the first antenna **16a** to the first transceiver **24a** and the fourth antenna **16d** to the second transceiver **24b**. In this latter circumstance, the antennas **16** that are contemporaneously connected to a respective one of the transceivers **24** may be spatially displaced to ensure no overlap. In other words, the switching network **28** may not simultaneously connect transceivers **24** to two antennas **16** located in adjacent lanes of the roadway **14**, since RF interference may result.

[0030] The switching network **28** operates under the control of the controller **26**, which causes the switching network **28** to connect and disconnect specified antennas **16** to selected transceivers **24** so as to implement a scanning pattern. The scanning pattern may include a fixed pattern of equal length timeslots. In some embodiments, the scanning pattern may include an adaptive pattern that adjusts to traffic volume differences between the laneways, as described in U.S. provisional Ser. No. 60/718,743, filed Sep. 21, 2005 and owned in common herewith, the contents of which are hereby incorporated.

[0031] The reader **30** may further include transceiver monitor circuitry **30** for providing the controller **26** with information regarding the transceiver(s) **24** and/or antennae **16**. In one embodiment, through the transceiver monitor circuitry **30** the controller **26** may receive a portion or sample of the RF signal output by each of the transceivers **24**. In another embodiment, the transceiver monitor circuitry **30** also or alternatively provides a portion or sample of the incoming RF signal input to the transceiver **24**.

[0032] Based upon the transceiver monitor circuitry **30**, the controller **26** may determine the power level of the output RF signal for the transceiver **24** and/or the power level of the input RF signal to the transceiver **24**. The controller **26** may also determine the voltage standing wave ratio (VSWR) of the RF output signal for the transceiver **24**. These signal characteristics may be used by the controller **26** to assess the transceiver **24** state and operating condition. For example, if the power level of the RF output signal drops below a threshold level, it may be indicative of a problem in the transceiver **24**. As another example, if the RF input signal has a strength that should be detectable by the transceiver **24** and the transceiver **24** does not detect the RF input signal, then it may indicate a problem with the sensitivity setting of the transceiver **24**. As yet another example, if the voltage standing wave ratio (VSWR) exceeds a threshold level, it may indicate a problem with the transceiver **24**, the transmission line to the antenna **16**, and/or the antenna **16** itself.

[0033] In one embodiment, the transceiver monitor circuitry **30** may include a directional coupler **31a**, **31b**, **31c** for obtaining a portion of each transceiver output. The directional couplers **31** may include a low loss tap for obtaining a small portion of the RF signal without significantly reducing the dBmV of the through signal. The transceiver monitor circuitry may further include directional couplers **33a**, **33b**, **33c** for obtaining a portion of the return signal to the transceivers **24**. The directional couplers **33a**, **33b**, **33c** may similarly include a low loss tap for obtaining a small portion of the RF signal without significantly reducing the dBmV of the through signal.

[0034] In one embodiment, the system **10** operates within the 915 MHz frequency band. In other embodiments, the

system **10** may use other frequency bands, such as, for example, 5.9 GHz. By way of example only, to minimize impact on the power transmitted to or from the antenna **16**, the directional couplers **31**, **33** may be 20 dB taps in which 99% of the power of the input signal passes through the directional couplers **31**, **33** and 1% of the power is split off for use in monitoring, as is described below. Selection of appropriate directional couplers **31**, **33** for a specific application will be within the knowledge of a person ordinarily skilled in the art.

[0035] The transceiver monitor circuitry **30** may further include processing circuitry **32**, **34** (shown individually as **32a**, **32b**, **32c**, **34a**, **34b**, **34c**). The tapped signals from the directional couplers **31**, **33**, may be filtered and/or digitized and/or otherwise processed in the processing circuitry **32a**, **32b**, **32c**, **34a**, **34b**, **34c**, respectively, before being provided to the controller **26**. The appropriate filtering, digitization, and other processing for the tapped signals in order to obtain information regarding the signal characteristics will be appreciated by those skilled in the art. The processing circuitry **32a**, **32b**, **32c**, **34a**, **34b**, **34c** may output measurement signals to the controller **26**.

[0036] In one embodiment the processing circuitry **32**, **34** may include threshold circuits for determining whether the RF power level of the tapped signal drops below a threshold level. The threshold level may be predetermined or may be controlled dynamically by the controller **26**. Output signals from the threshold circuitry corresponding to each transceiver **24** may be input to the controller **26**. On this basis, the controller **26** may assess whether the individual transceivers **24** are operating normally. The threshold circuitry **32** may include various discrete components, including filters, etc., for determining or detecting the power level of an RF signal and comparing it against a threshold level, as will be appreciated by those of ordinary skill in the art.

[0037] Reference is made to FIG. 5, which diagrammatically shows an example embodiment of a portion of the transceiver monitor circuitry **30**. The circuitry **30** includes the directional coupler **31** for obtaining a portion of the output signal from the transceiver **24** (FIG. 1). The directional coupler **31** outputs the portion as a tapped signal **38**. The tapped signal **38** is input to the processing circuitry **32**. In this embodiment, the processing circuitry **32** includes a down-converter or mixer **40** and a peak detector **41**. The mixer **40** receives the tapped signal **38** and the carrier frequency, which in some embodiments is in the 915 MHz band, and outputs a baseband or IF signal. This signal is then input to the peak detector **41**, which outputs a DC signal **42** that has a voltage level that may be used as a proxy for measuring the power output level of the transceiver **24**.

[0038] The processing circuitry **32** may also include a comparator **46**. The comparator **46** receives, as inputs, the DC signal **42** and a threshold signal **44**. The threshold signal **44** has a pre-set DC level that represents the minimum level that the DC signal **42** must exhibit. If the DC signal **42** falls below the threshold signal **44** level, it is indicative that the output power of the transceiver **24** has fallen below the minimum level permitted. The threshold signal **44** may be predetermined through a voltage divider within the processing circuitry **32**. In another embodiment, the threshold signal **44** is generated by a digital circuit pre-programmed to output the threshold signal **44** and the predetermined level. In yet

another embodiment, the threshold signal 44 is output by a signal generator circuit 52 operating under the control of the controller 26. In such an embodiment, the controller 26 may adjust the level of the threshold signal 44 from time-to-time.

[0039] The comparator 46 outputs a result signal 50 based upon the comparison between the DC signal 42 and the threshold signal 44. For example, the comparator 46 may output a LOW signal if the DC signal 42 remains above the threshold signal 44, and may output a HIGH signal if the DC signal 42 falls below the threshold signal 44. In some embodiments, the comparator 46 may be implemented using an op-amp or similar integrated circuit. The result signal 50 may be buffered through a buffer circuit 48 before being input to a failure detection input port 54 of the controller 26.

[0040] It will be appreciated that similar circuitry may be used in conjunction with the directional coupler 33 to implement the processing circuitry 34 for tapping and analyzing the RF input signal. The down-converted and peak-detected RF input signal may be compared with a minimum detectable threshold signal that is preset to indicate the minimum RF level at which the transceiver 24 sensitivity ought to be set in order to detect a response signal from a transponder. A concurrent failure by the transceiver 24 to detect a response signal when the RF input signal has a power level above the threshold indicates that the transceiver 24 input stage sensitivity requires some adjustment or has failed altogether.

[0041] Reference is now made to FIG. 6, which shows another example embodiment of a portion of the transceiver monitor circuitry 30. In this embodiment, the transceiver monitor circuitry 30 includes the mixer 40 and the peak detector 41 and includes an analog-to-digital converter 60 for receiving the DC signal 42 and converting it to a digital signal 62. The analog-to-digital converter 60 quantizes and digitizes the DC signal 42, outputting the digital signal 62 containing data regarding the signal level of the DC signal 42. The digital signal 62 may then be input to the controller 26, which may, through operations implemented in software or firmware, analyze the digital signal 62 to detect whether the output signal level of the transceiver 24 falls below a predetermined threshold.

[0042] Other methods and mechanisms for implementing the transceiver monitor circuitry 30, and the processing circuitry 32, 34 in particular, will be understood by those of ordinary skill in the art having regard to the present description.

[0043] Reference is again made to FIG. 1. The transceivers 24 may each include one or more digital attenuators 36 (shown individually as 36a, 36b, 36c) or other adjustable elements. The digital attenuators 36 may be programmable adjustable impedances placed in line with the RF input port or output port of the transceiver 24. Through control signals from the controller 26, the setting of the digital attenuators 36 may be adjusted. Accordingly, the controller 26 may boost RF output signal power by adjusting the setting of the digital attenuator 36 within the transceiver 24, or may change the transceiver 24 sensitivity for detecting RF input signals. In this regard, the controller 24 may adapt or control the RF output and/or input of the transceiver 24 in response to the measurement signals received from the transceiver monitor circuitry 30. The digital attenuators 36 allow the controller 26 to retune the transceiver 24 to compensate for

component drift within the transceiver 24 or degradation in the transmission line or antenna 16.

[0044] Reference is now also made to FIG. 2, which shows another block diagram of the ETC system shown in FIG. 1. The controller 26 may include a data port for exchanging data with a communication subsystem 40 (FIG. 1). The communication subsystem 40 facilitates communication with a remote system through a network (indicated generally using reference number 50). In some embodiments, the communication subsystem 40 may include a serial data port, a wireless communications port, a modem, or other system for sending and receiving data communications with a remote computer and/or system. The communication subsystem 40 is operable to output a communication signal to a remote destination and to receive a communication signal from the remote destination.

[0045] In one embodiment the communication subsystem 40 is configured to send and receive data with a remote computer or client device 80 over the network 50. The remote client device 80 monitors the state and operation of the reader 20 and other readers in an overall electronic toll transaction system. The remote client device 80 may further provide instructions to individual readers by way of a data communication signal sent to the communications subsystem 40. In this regard, the remote client device 80 may monitor the reader 20 performance, including the performance of the individual transceiver(s) 24, and may make adjustments by way of the digital attenuators 36 within the respective transceivers 24.

[0046] In one embodiment, the communication subsystem 40 operates as a server in relation to the client device 80. For example, the subsystem 40 may implement an http server for receiving and responding to information requests from the remote client device 80 over the network 50. The communications subsystem 40 may include one or more mark-up language documents configured to contain data regarding the transceivers 24, their state, operating parameters, and other data. The documents may be created using HTML, XML, or any other suitable mark-up language.

[0047] The subsystem 40, together with the controller 26, may be configured to receive authenticated instructions to vary one or more parameters, such as the setting of one of the digital attenuators 36, from the remote client device 80 over the network 50. Various security mechanisms and protocols may be implemented by the subsystem 40 to ensure that the reader 20 and parameters within the transceivers 24 are altered only by authorized persons.

[0048] The network 50 may be private, public, or a combination of both. The network 50 may be wired or wireless or a combination thereof. In one embodiment, the network 50 includes the Internet.

[0049] Reference is now made to FIGS. 3 and 4, which show, in flowchart form, a method 100 for monitoring and adjusting transceivers in an electronic toll collection system.

[0050] The method 100 begins in step 102 with the transmission of the RF trigger signal by one of the transceivers. The transceiver generates an RF output signal conforming to the predefined communications protocol. By way of example, the RF trigger signal may be a burst of RF energy at about 915 MHz for a predefined pulse duration, such as about 20 Ps.

[0051] The transceiver monitor circuitry taps the outgoing RF trigger signal to obtain a tapped signal. The power level of the tapped signal is compared to a threshold level to determine whether the outgoing RF trigger signal meets the minimum power level requirement. In step 104, it is determined whether the transceiver generated an RF trigger signal having sufficient power. If so, then the method 100 continues at step 106. Otherwise, the method 100 proceeds to step 108.

[0052] In step 108, it is determined whether the problem is correctable through adjustment. For example, if the RF output power is slightly low and if the transceiver includes a mechanism, such as a programmable attenuator, in its output path that may be adjusted to provide a power boost, then the problem may be correctable. If the mechanism has reached a limit point, then the problem may not be correctable. For example, this may occur if the programmable attenuator has reached a boundary maximum beyond which it cannot be further adjusted. Step 108 may include testing various conditions, such as whether the RF output power is sufficiently close to zero to indicate total failure in the transceiver, or whether the adjustment mechanism has scope for further adjustment. If the problem appears correctable, then the method 100 continues to step 110.

[0053] In step 110, the adjustment required to compensate for the low power output from the transceiver. It will be appreciated that various algorithms may be used to determine an appropriate adjustment to bring the output power level up to an acceptable level.

[0054] If the problem cannot be corrected through an adjustment to the transceiver, then the method 100 jumps to step 112, wherein the transceiver is disabled. This may include excluding the transceiver from use in the scanning pattern and replacing it with a redundant transceiver, or shifting its load onto other transceivers in the reader.

[0055] In any event, following step 112 or 110 in step 114 a report or alert message may be generated and/or output from the reader to indicate that a problem was detected with one of the transceivers. The report or message may be logged to memory within the reader, may be output through the communications subsystem, and/or may be displayed or otherwise output locally. The message may indicate the nature of the problem detected, including measurement data, and which transceiver was determined to be deficient.

[0056] If, in step 104, no problem is detected with the RF output power from the transceiver, then the method 100 proceeds to step 106, where the VSWR is assessed. The VSWR is the ratio of the reflected signal power to the outgoing signal power. Ideally the VSWR is zero, meaning that no energy is reflected back and it is all propagated from the antenna as RF waves. However, various discontinuities and mismatches in the transmission line, antenna, and various couplings and connectors along the signal path may give rise to reflected energy. The transceiver monitor circuitry taps the input RF signal that arises during the transmission of the RF trigger signal and based upon it, and the tapped RF output signal, the VSWR is assessed. If the VSWR rises above a maximum limit, it is indicative of degraded or damaged transmission facilities.

[0057] If a problem is detected in step 106, then the method 100 jumps to step 114. A problem with the VSWR

is most likely an issue in an antenna or transmission line, which likely cannot be corrected or compensated for through adjusting the transceiver output or sensitivity. Accordingly, detection of the VSWR leads to generation of a report or message indicating the detected problem. The report or message may include information regarding the transceiver, antenna, and measured data to enable personnel to identify and diagnose the potential problem.

[0058] After step 114, or after it is determined that no problems exist in step 106, then the method 100 continues in step 116 in which an RF input signal is received. In step 118, using the transceiver monitor circuitry, the reader assesses whether the RF input signal falls below the minimum level that should be detectable by the transceiver in detecting a response signal from a transponder. If the RF input signal is above the minimum level, then in step 120 the reader assesses whether the transceiver detects the RF input signal. If not, then it is indicative of a problem with the sensitivity of the RF input stage of the transceiver, and the method 100 proceeds to step 122.

[0059] In step 122, the controller assesses whether the problem with transceiver sensitivity can be corrected through adjustment of a programmable attenuator or other adjustable element within the RF input stage of the transceiver. The adjustable element may not have further scope for adjustment—i.e. it may have reached a maximum or minimum setting. Alternatively, the magnitude of the problem, if the measured RF input level is reasonable robust, may indicate a total failure of the transceiver RF input stage rather than a drift in the sensitivity setting. In either case, the problem may not be correctable through adjustment. In these circumstances, the method 100 may proceed to step 124 to disable the transceiver, effectively by excluding it from use in the scanning functions of the reader.

[0060] If the problem appears correctable, then in step 126 an appropriate adjustment is calculated by the controller and the controller sends a signal or command to the adjustable element, such as a programmable attenuator, to change its setting.

[0061] After steps 124 or 126, a report or message is generated, as was described above in connection with step 114. Then the method 100 may return to step 102.

[0062] It will be appreciated that during operation of any of the foregoing methods, the various parameters and test results obtained through the transceiver monitor circuitry and input to the controller may be logged or saved to memory. For example, the reader may include volatile or non-volatile memory, such as flash memory, to which the transceiver data may be logged from time-to-time. In some embodiments, the logged data may be accessed by the remote client devices through the communications subsystem. In another embodiment, the logged data is periodically “pushed” to a remote location over the network as a reporting function of the controller and communications subsystem.

[0063] The setting of the various threshold maximum and minimum signal levels in particular applications will be within the understanding of a person of ordinary skill in the art.

[0064] The present invention may be embodied in other specific forms without departing from the spirit or essential

characteristics thereof. Certain adaptations and modifications of the invention will be obvious to those skilled in the art. Therefore, the above discussed embodiments are considered to be illustrative and not restrictive, the scope of the invention being indicated by the appended claims rather than the foregoing description, and all changes which come within the meaning and range of equivalency of the claims are therefore intended to be embraced therein.

What is claimed is:

1. A electronic toll collection system for conducting toll transactions with vehicle-mounted transponders travelling in a roadway, the electronic toll collection system comprising:

at least one antenna having a coverage area for exchanging RF communications with a transponder in the roadway; and

a reader connected to said at least one antenna, said reader including

a transceiver having an RF port for exciting the at least one antenna with an RF output signal and for receiving RF input signals induced in the at least one antenna by the transponder, the transceiver including an adjustable element having a setting responsive to an adjustment signal,

a controller for controlling said transceiver and for outputting said adjustment signal, and

a transceiver monitor circuit connected to the RF port for measuring characteristics of the RF output signal and the RF input signal, said transceiver monitor circuit providing a result signal to said controller,

and wherein said controller is configured to generate said

adjustment signal based upon said result signal.

2. The system claimed in claim 1, wherein said adjustable element comprises a programmable attenuator.

3. The system claimed in claim 1, wherein said transceiver includes an RF output stage for generating said RF output signal, said RF output stage including said adjustable element, and wherein said setting of said adjustable element determines a power level of said RF output signal.

4. The system claimed in claim 1, wherein said transceiver includes an RF input stage for receiving and detecting said RF input signal, said RF input stage including said adjustable element, and wherein said setting of said adjustable element determines a sensitivity of said RF input stage in detecting said RF input signal.

5. The system claimed in claim 1, wherein said transceiver monitor circuit comprises a low loss directional coupler and processing circuitry, and wherein said processing circuitry includes a down-converter, a peak detector, and a comparator for determining whether the RF output signal has a power level above a minimum threshold level, and wherein the result signal indicates whether the RF output signal power level exceeds the minimum threshold level.

6. The system claimed in claim 5, wherein the controller is configured to calculate an adjustment for the adjustable element based upon the result signal and to generate said adjustment signal to implement said adjustment.

7. The system claimed in claim 1, wherein said transceiver monitor circuit comprises a low loss directional coupler and processing circuitry, and wherein said processing circuitry

includes a down-converter, a peak detector, and a comparator for determining whether the RF input signal has a power level above a minimum threshold level, and wherein the result signal indicates whether the RF output signal power level exceeds the minimum threshold level.

8. The system claimed in claim 7, wherein the controller is configured to determine whether the transceiver detects the RF input signal and, if not, to calculate an adjustment for the adjustable element based upon the result signal and to generate said adjustment signal to implement said adjustment.

9. The system claimed in claim 1, wherein said transceiver monitor circuit and said controller are configured to determine the VSWR of the RF output signal and to compare the VSWR to a threshold level.

10. The system claimed in claim 1, wherein said controller is configured to generate and output a report in response to said result signal.

11. The system claimed in claim 1, wherein said controller includes a communications subsystem and a data output port, and wherein said communication subsystem is configured to output data regarding said measured characteristics of the RF output signal and the RF input signal.

12. The system claimed in claim 11, wherein the communications subsystem is configured to generate a mark-up language document containing said measured characteristics, and to transmit said mark-up language document to a remote client device in response to an authenticated request from the remote client device.

13. A method of monitoring operation of an electronic toll collection system for conducting toll transactions with vehicle-mounted transponders travelling in a roadway, the system including at least one antenna having a coverage area for exchanging RF communications with a transponder in the roadway and a reader connected to the at least one antenna, wherein the reader includes a transceiver having an RF port for exciting the at least one antenna with an RF output signal and for receiving RF input signals induced in the at least one antenna by the transponder, the transceiver including an adjustable element having a setting responsive to an adjustment signal, and a controller for controlling said transceiver and for outputting said adjustment signal, the method comprising steps of:

measuring characteristics of the RF output signal and the RF input signal;

calculating an adjustment based upon the measured characteristics; and

generating said adjustment signal to implement said calculated adjustment.

14. The method claimed in claim 14, wherein said adjustable element comprises a programmable attenuator.

15. The method claimed in claim 14, wherein said transceiver includes an RF output stage for generating said RF output signal, said RF output stage including said adjustable element, and wherein said setting of said adjustable element determines a power level of said RF output signal.

16. The method claimed in claim 14, wherein said transceiver includes an RF input stage for receiving and detecting said RF input signal, said RF input stage including said adjustable element, and wherein said setting of said adjustable element determines a sensitivity of said RF input stage in detecting said RF input signal.

17. The method claimed in claim 14, wherein said step of measuring includes determining whether the RF output signal has a power level above a minimum threshold level.

18. The method claimed in claim 17, wherein said step of calculating includes determining whether said adjustment may be implemented through the adjustable element.

19. The method claimed in claim 14, wherein said step of measuring includes determining whether the RF input signal has a power level above a minimum threshold level and, if so, determining whether the transceiver detects the RF input signal.

20. The method claimed in claim 14, wherein said step of measuring includes measuring the power of the RF output

signal and measuring the reflected power and calculating the VSWR of the RF output signal.

21. The method claimed in claim 14, further including generating and outputting a report regarding said measured characteristics.

22. The method claimed in claim 21, wherein said report includes a mark-up language document containing said measured characteristics, and wherein said step of outputting includes transmitting said report to a remote client device in response to an authenticated request from the remote client device.

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