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(54) **WIRELESS CONNECTIONS WITH VIRTUAL HYSTERESIS**

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See application file for complete search history.

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This patent is subject to a terminal disclaimer.

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(57) **ABSTRACT**

Circuit connectors for establishing EHF communication include a receiver configured to receive a transmitted EHF electromagnetic signal, and an output circuit coupled to the receiver. The output circuit has two states of operation that correspond to enabling a signal output and disabling the signal output. The output circuit is also configured to change its state of operation responsive to a state of a control signal, and a controller is coupled to the receiver and configured to produce the control signal. The control signal has two states that correspond to a first condition when the received signal exceeds a first threshold and a second condition when the received signal is less than a second threshold.

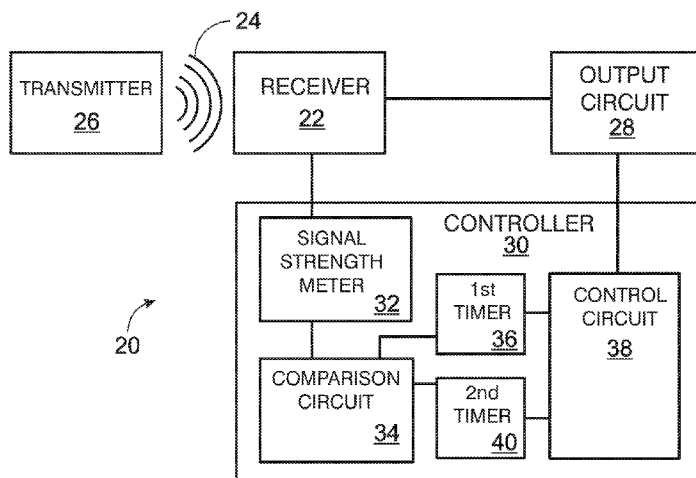
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Fig. 1

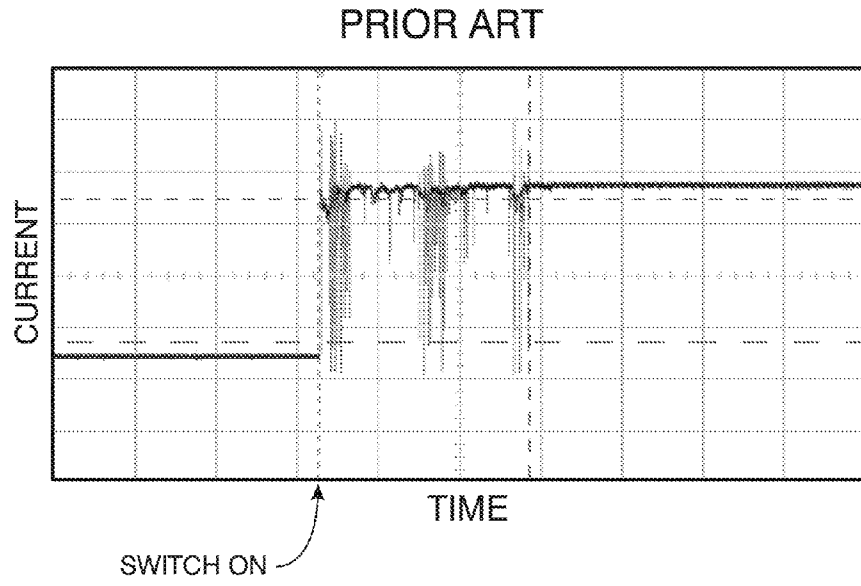


Fig. 2

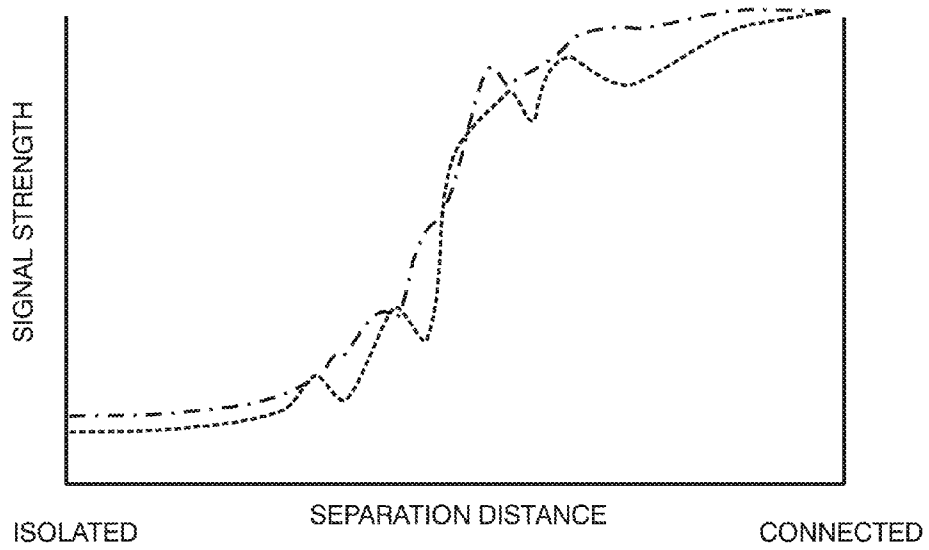


Fig. 3

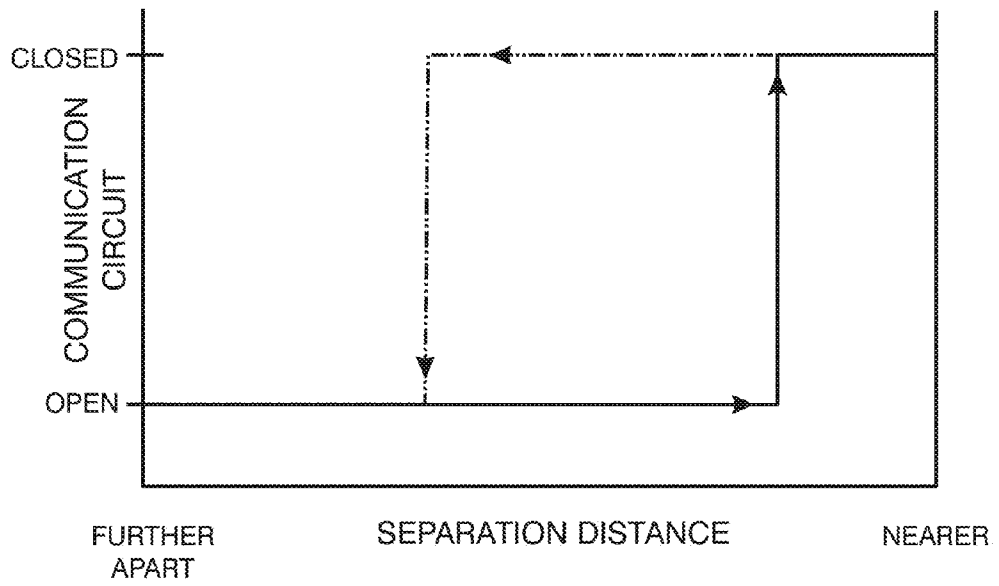


Fig. 4

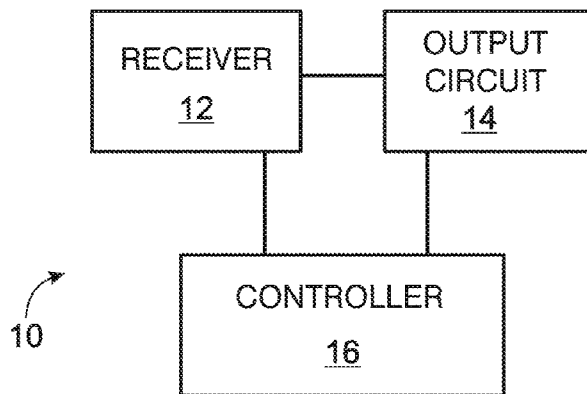


Fig. 5

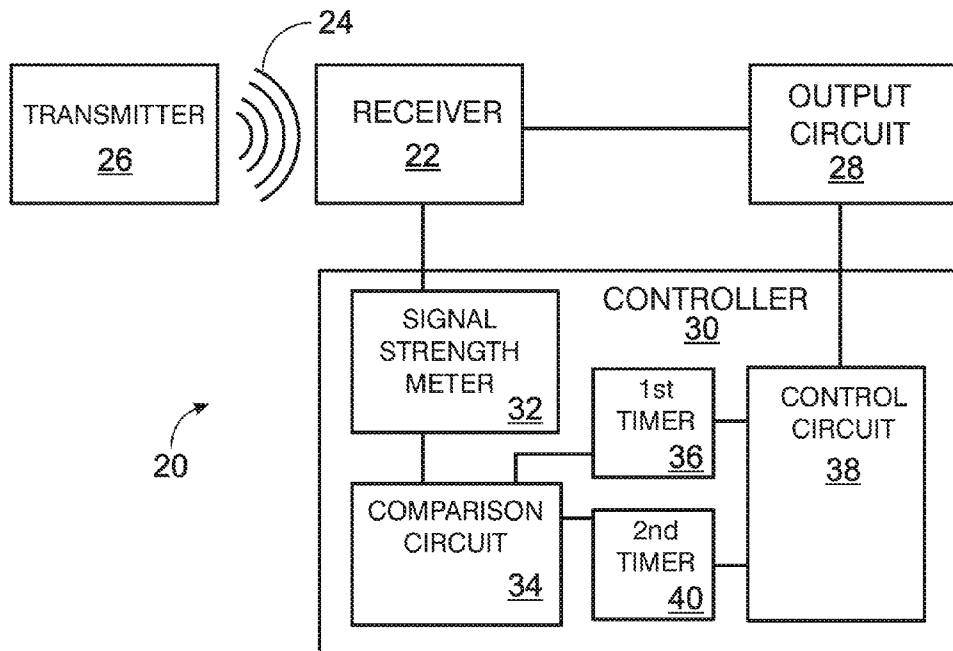


Fig. 7

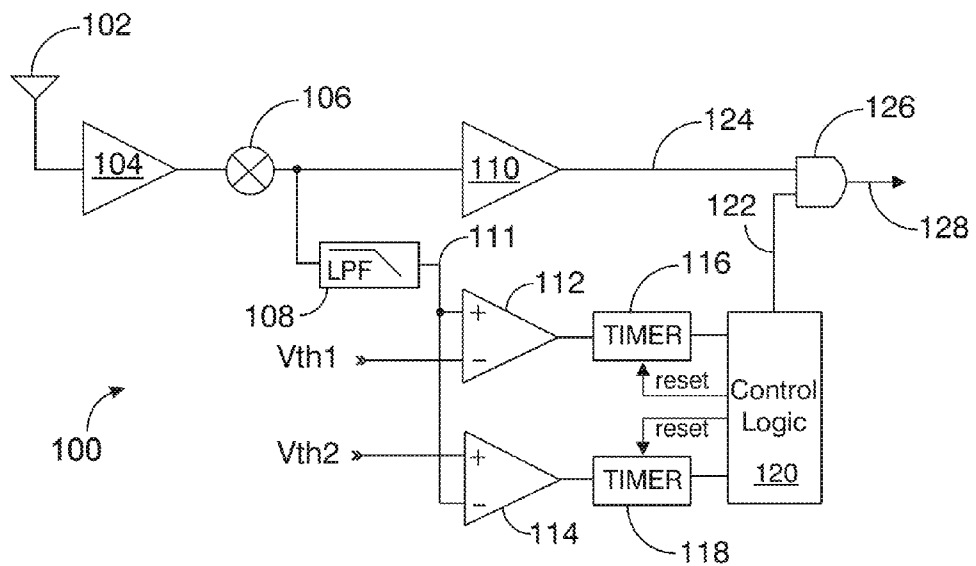


Fig. 6

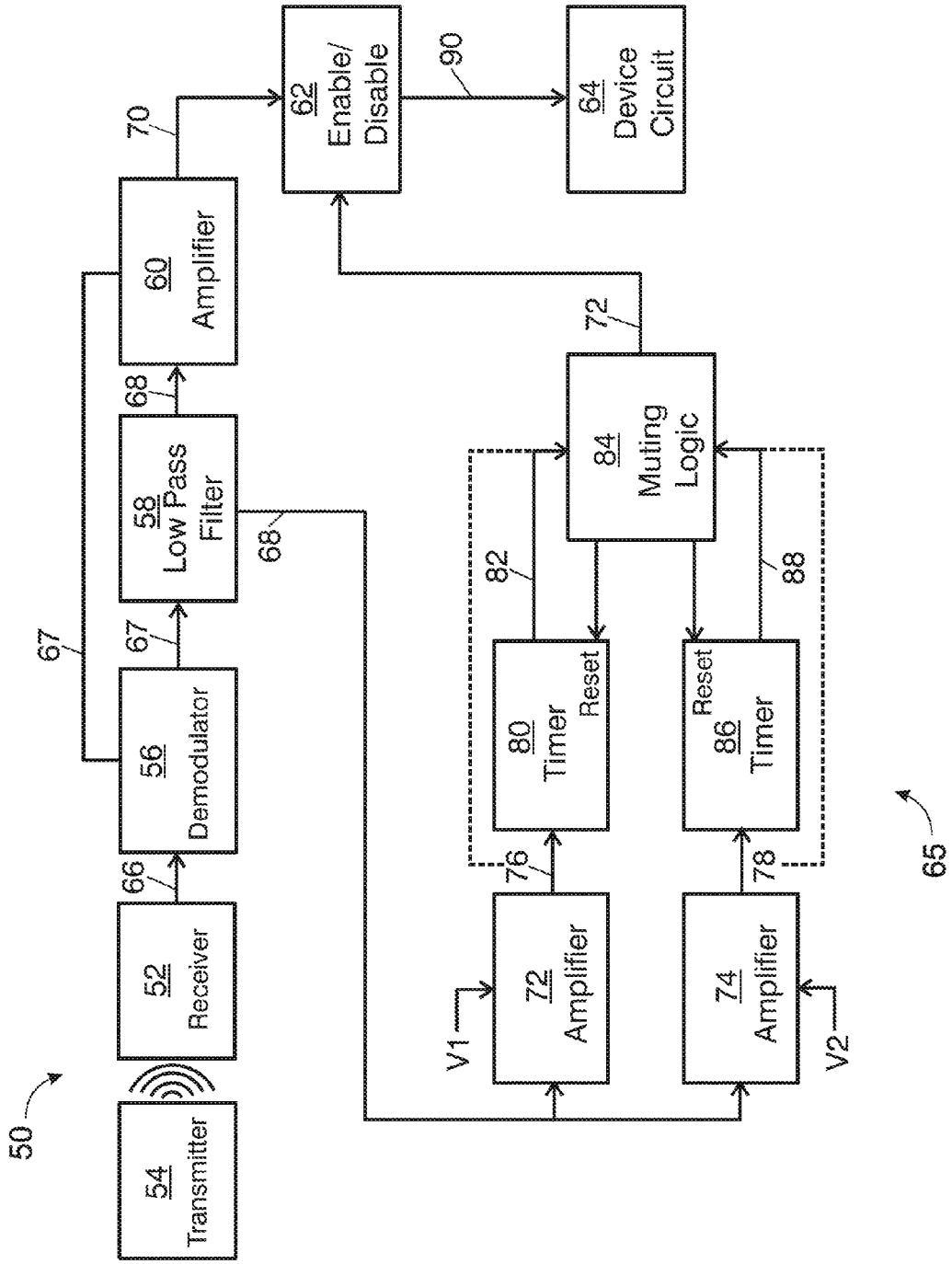


Fig. 8

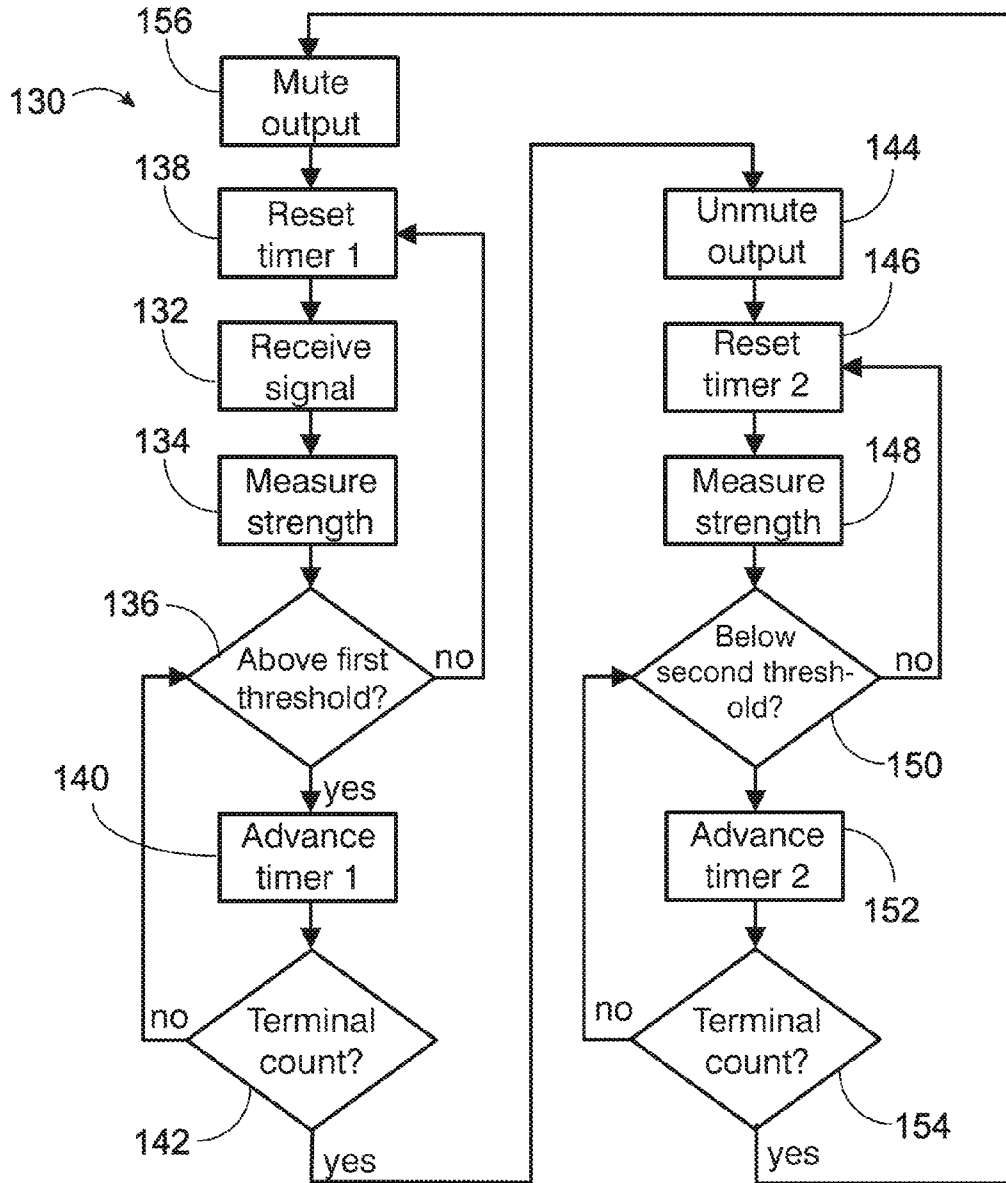


Fig. 9

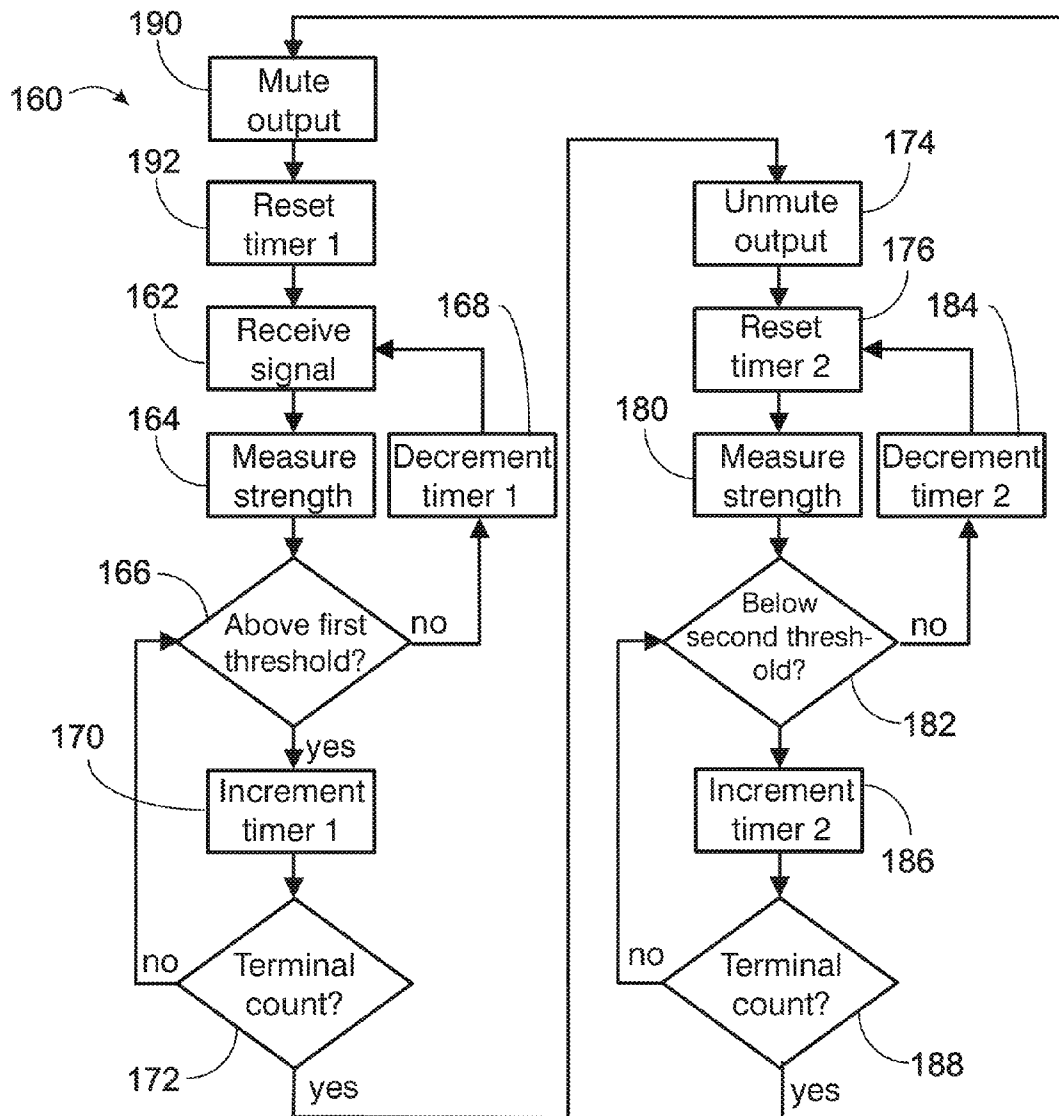


Fig. 10

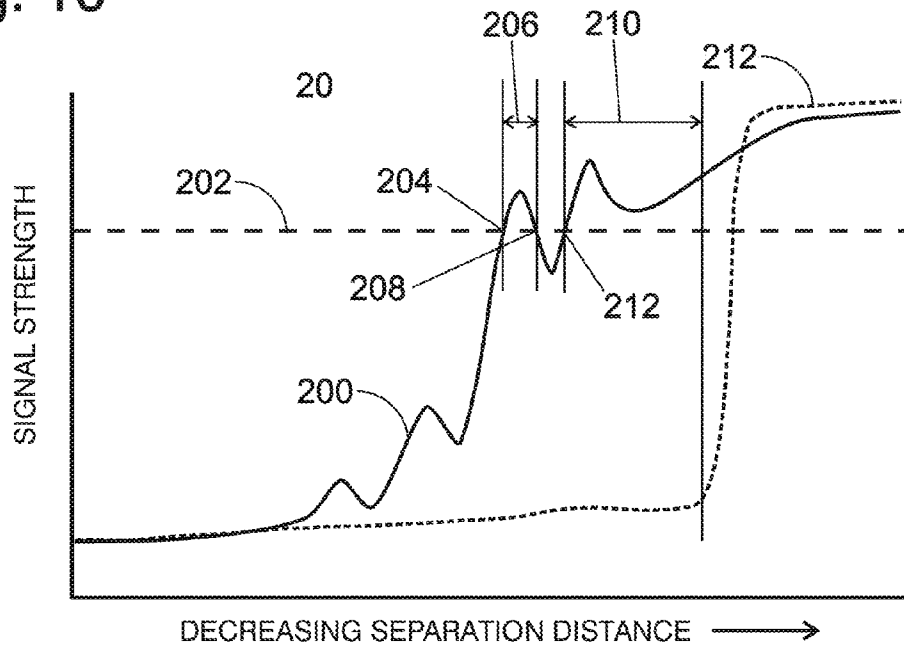


Fig. 11

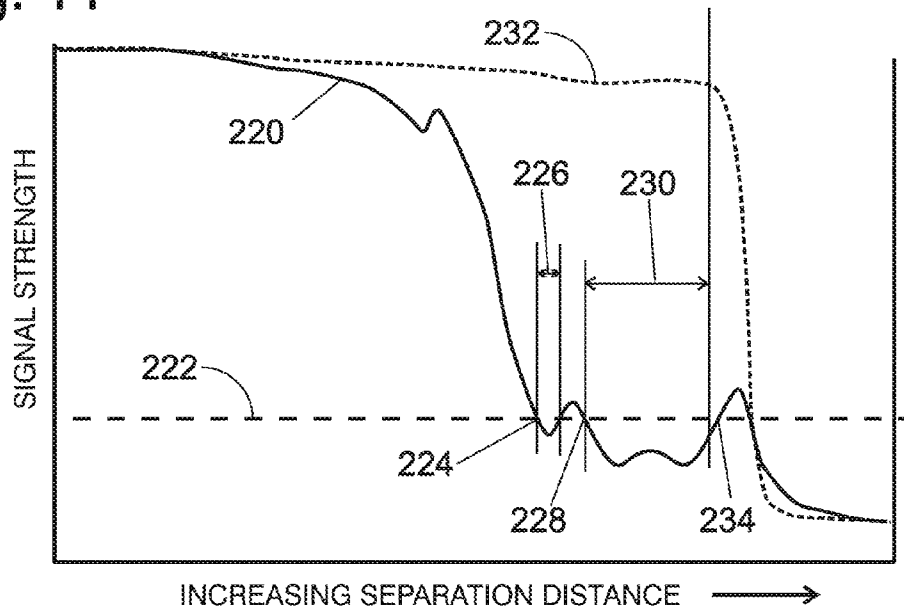


Fig. 12

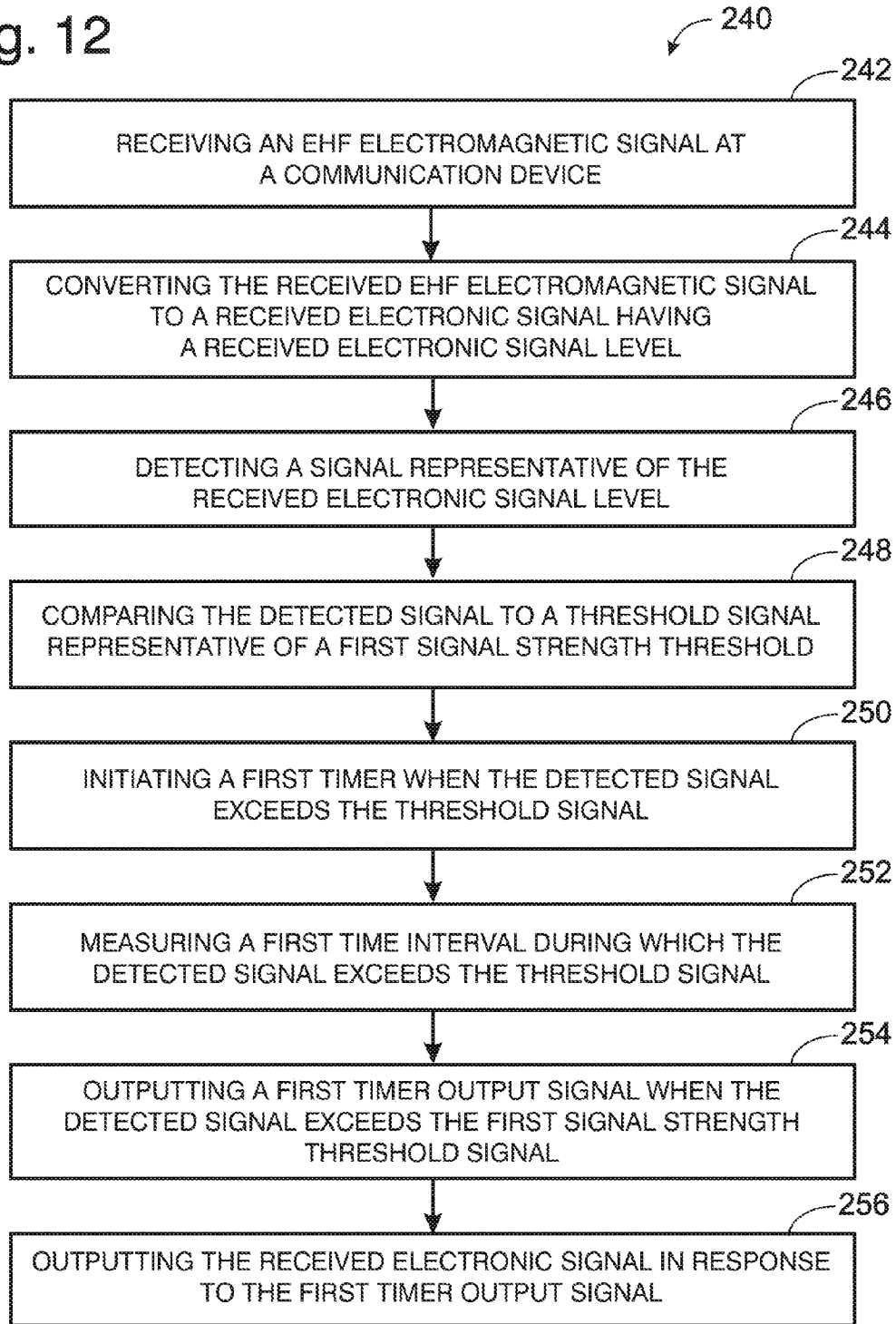


Fig. 13

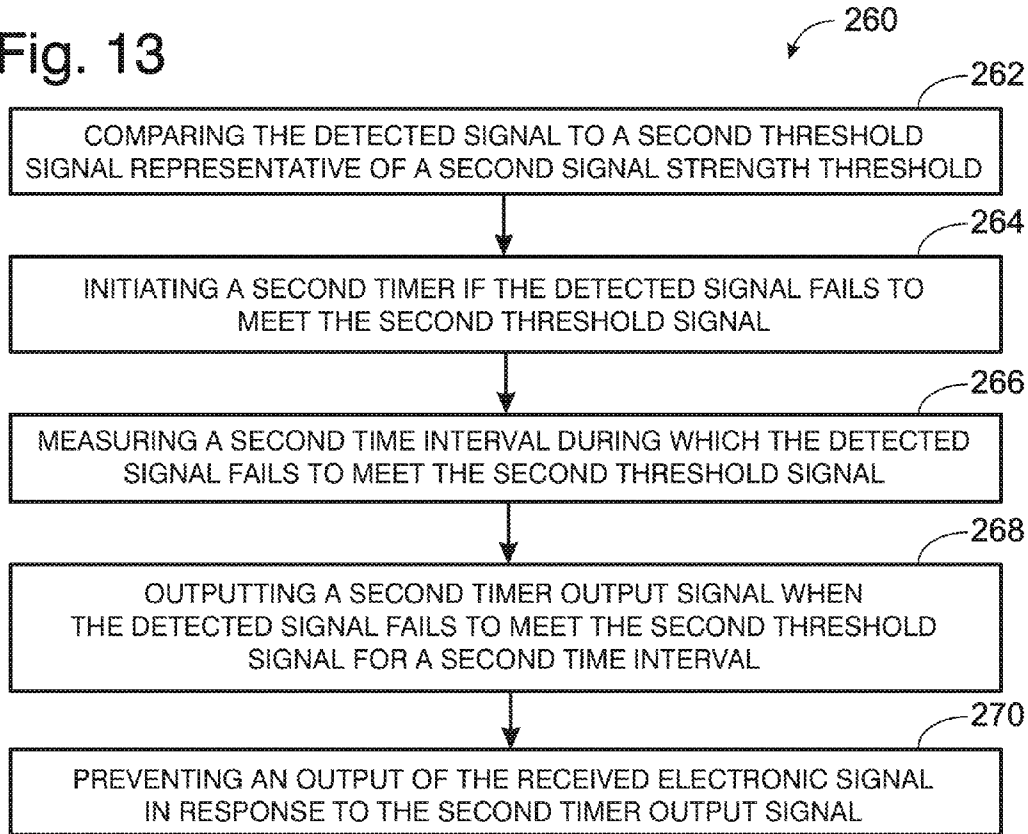


Fig. 14

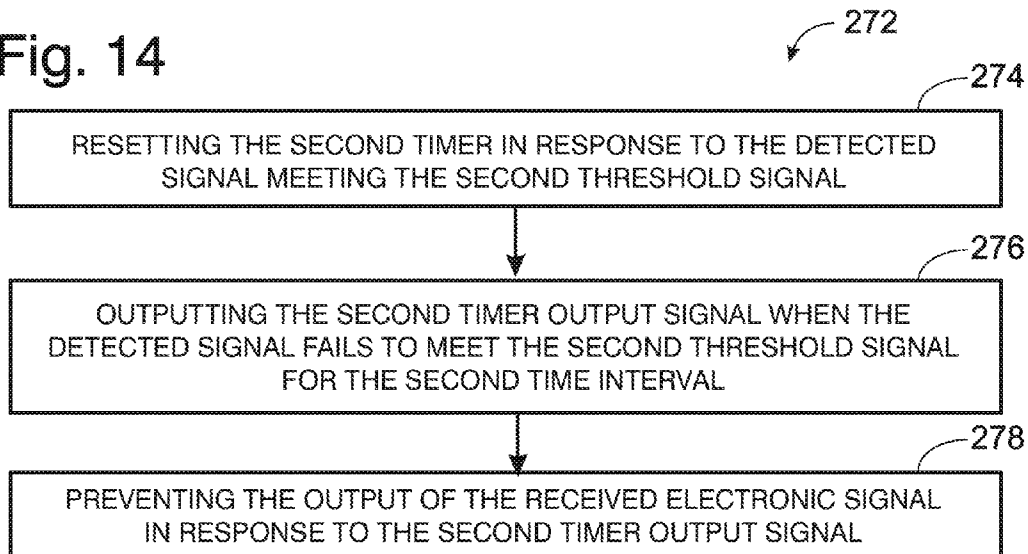
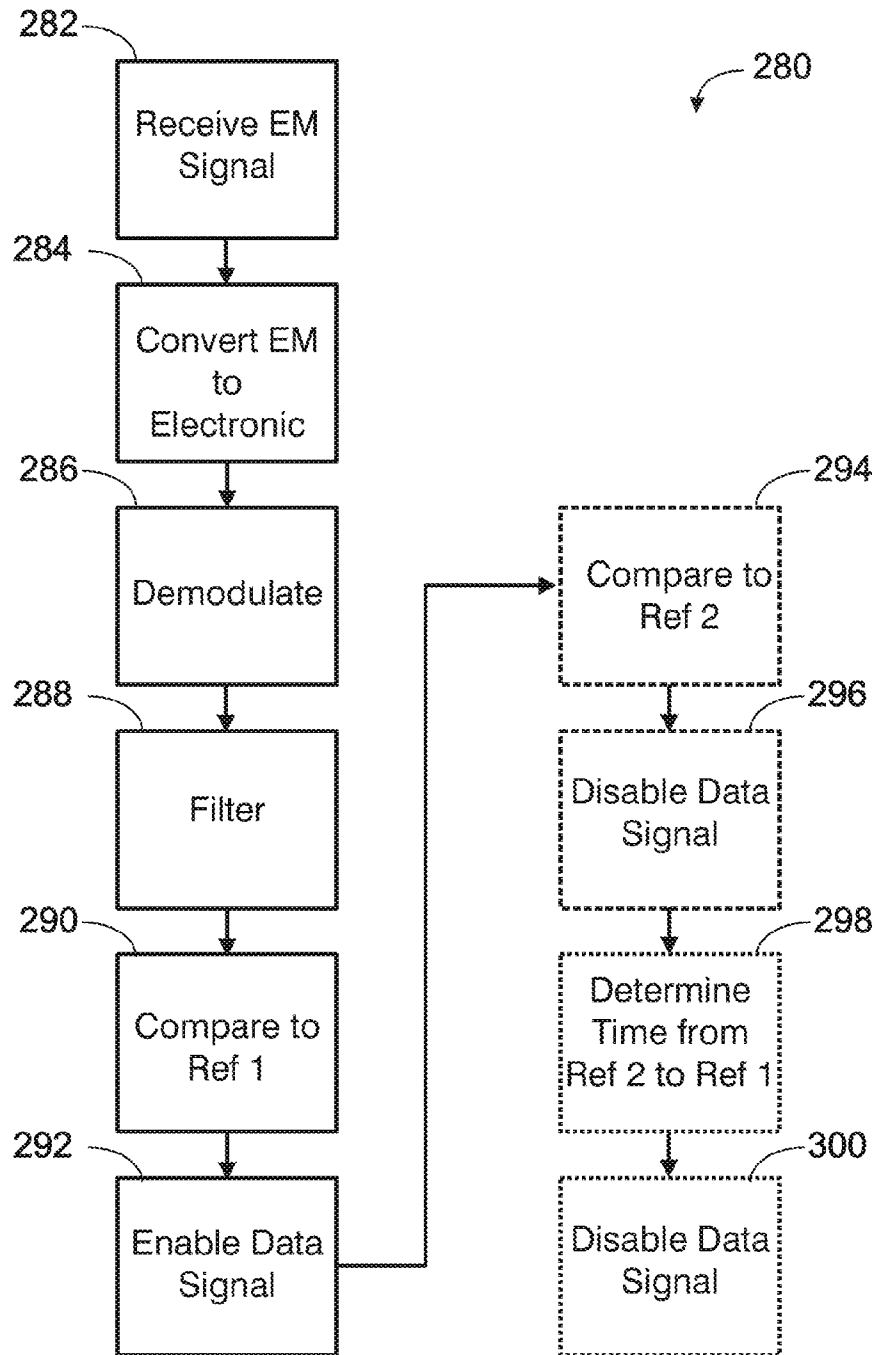


Fig. 15



WIRELESS CONNECTIONS WITH VIRTUAL HYSTERESIS

CROSS-REFERENCE TO RELATED PATENTS AND APPLICATIONS

The present application claims the benefit under 35 U.S.C. §120 of prior, co-pending U.S. patent application Ser. No. 14/026,913 for WIRELESS CONNECTIONS WITH VIRTUAL HYSTERESIS, filed on Sep. 13, 2013, which claims the benefit under 35 U.S.C. §119(e) of the filing date of provisional application Ser. No. 61/701,310 for VIRTUAL PHYSICAL HYSTERESIS, filed Sep. 14, 2012, both of which are hereby incorporated by reference in its entirety for all purposes. U.S. patent application Ser. No. 13/427,576 for INTEGRATED CIRCUIT WITH ELECTROMAGNETIC COMMUNICATION is also incorporated by reference in its entirety for all purposes.

TECHNICAL FIELD

The present invention generally relates to devices, systems, and methods for EHF communications, and more particularly to establishing and terminating EHF electromagnetic connections.

BACKGROUND

Contact bounce, or chatter, is a rapid current switching or flickering that may occur upon the closure of a mechanical switch or relay. It may occur when the electrical contacts in the switch have sufficient resilience, or springiness, that when they are brought into contact with one another they may rebound slightly, almost as if bouncing, before a steady constant contact is established. The result is an initial rapid current oscillation instead of the expected instantaneous transition from zero to full current. An exemplary plot showing an example of contact bounce as exhibited by a mechanical switch is shown in FIG. 1.

Although they do not possess mechanical switches, contactless connectors such as those described in U.S. patent application Ser. No. 13/427,576 (hereby incorporated by reference) may also suffer from rapid initial changes in signal strength as the connectors are brought into sufficient proximity to establish the desired wireless connection. Variations in electromagnetic field homogeneity, small changes in relative antenna orientations, and other factors may all contribute to such observed signal variations, which may compromise the initial stability of the connection.

What is needed is a contactless circuit connector that can prevent or compensate for such initial variations in signal strength, so as to ensure that even at the initial stages of establishing a contactless connection, the connection is nevertheless both robust and consistent.

SUMMARY

In one embodiment, the present invention provides a circuit connector for communicating between devices, where the circuit connector includes a receiver configured to receive a transmitted EHF electromagnetic signal, an output circuit coupled to the receiver and that is responsive to a control signal for outputting an output signal representative of the received signal when the control signal has a first state and for not outputting the output signal when the control signal has a second state, and a controller coupled to the receiver and configured to produce the control signal having

the second state until a signal strength of the received signal exceeds a first threshold for a first time interval, whereupon the controller produces the control signal having the first state, and the controller is configured to produce the control signal with the second state when the signal strength of the received signal fails to meet a second threshold for a second time interval.

In another embodiment, the present invention provides a circuit connector for communicating between devices that includes an output circuit coupled to a receiver, where the output circuit is responsive to a control signal for outputting an output signal representative of a received signal when the control signal has a first state and for not outputting the output signal when the control signal has a second state. The circuit connector further includes a controller coupled to the receiver and configured to produce the control signal having the second state until a signal strength of the received signal exceeds a first threshold, whereupon the controller produces the control signal having the first state, and to produce the control signal with the second state when the signal strength of the received signal fails to meet a second threshold for a second time interval.

In yet another embodiment, the present invention provides a method for establishing an electronic signal using a circuit connector configured to communicate via EHF electromagnetic signals. The method includes receiving an EHF electromagnetic signal at the circuit connector, converting the received EHF electromagnetic signal to a received electronic signal having a received electronic signal level, detecting a signal representative of the received electronic signal level, comparing the detected signal to a threshold signal representative of a first signal strength threshold, initiating a first timer when the detected signal exceeds the threshold signal, measuring a first time interval during which the detected signal exceeds the threshold signal, outputting a first timer output signal when the detected signal exceeds the first signal strength threshold for the first time interval, outputting the received electronic signal in response to the first timer output signal, comparing the detected signal to a second threshold signal representative of a second signal strength threshold; initiating a second timer if the detected signal fails to meet the second threshold signal; measuring a second time interval during which the detected signal fails to meet the second threshold signal; outputting a second timer output signal when the detected signal fails to meet the second threshold signal for a second time interval; and preventing an output of the received electronic signal in response to the second timer output signal.

In yet another embodiment, the present invention provides a method for establishing an electronic signal using a circuit connector device configured to communicate via EHF electromagnetic signals. The method includes receiving an EHF electromagnetic signal at the circuit connector, converting the received EHF electromagnetic signal to a received electronic signal having a received electronic signal level, detecting a signal representative of the received electronic signal level, comparing the detected signal to a threshold signal representative of a first signal strength threshold; measuring the amount of time the detected signal exceeds the first threshold signal, outputting a first output signal when the detected signal exceeds the first threshold signal for a first time interval, and outputting the received electronic signal in response to the first output signal.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a plot illustrating contact bounce when closing a mechanical switch.

FIG. 2 is a representative plot of signal strength between contactless connection components as a function of separation distance, with the dashed line depicting variability in signal strength as a contactless connection is formed, and with the dot-dashed line depicting variability in signal strength as a contactless connection is terminated. Equal and constant rate of change of separation distance is assumed for both plots.

FIG. 3 is a representative plot showing the hysteresis exhibited while establishing and terminating a contactless communication circuit according to an embodiment of the present invention.

FIG. 4 is a block diagram depicting an exemplary circuit connector according to an embodiment of the present invention.

FIG. 5 is a block diagram depicting an alternative circuit connector according to an embodiment of the present invention.

FIG. 6 is a block diagram showing an exemplary system for implementing a virtual hysteresis response, according to an embodiment of the present invention.

FIG. 7 is an electronic circuit schematic diagram depicting an exemplary circuit for implementing a virtual hysteresis response, according to an embodiment of the present invention.

FIG. 8 is a flowchart depicting an exemplary sequence of events when implementing a virtual hysteresis response, according to an embodiment of the present invention.

FIG. 9 is a flowchart depicting an alternative exemplary sequence of events when implementing a virtual hysteresis response, according to an alternative embodiment of the present invention.

FIG. 10 is a plot depicting the effect of an applied virtual hysteresis on signal strength during the formation of a contactless connection, according to an embodiment of the present invention.

FIG. 11 is a plot depicting the effect of an applied virtual hysteresis on signal strength during the termination of a contactless connection, according to an embodiment of the present invention.

FIG. 12 is a flowchart illustrating an exemplary method according to an embodiment of the present invention.

FIG. 13 is a flowchart illustrating an optional extension of the flowchart of FIG. 12.

FIG. 14 is a flowchart illustrating an optional extension of the flowchart of FIG. 13.

FIG. 15 is a block diagram showing another exemplary system for implementing a virtual hysteresis response, according to an embodiment of the present invention.

DESCRIPTION OF PREFERRED EMBODIMENTS

Conventional physical connections between devices or circuits exhibit a variety of detrimental characteristics when employed in electronic systems that are designed to transfer data at very high rates, resulting in degradation of signal integrity and a corresponding system instability. Physical connections may be eliminated by using wireless communication systems, such as are disclosed in U.S. Pat. No. 5,621,913 and U.S. Pat. No. 8,554,136 (the disclosures of these and all other publications referenced herein are incorporated by reference in their entirety for all purposes).

However, such wireless systems are not able to accommodate the ever-increasing demands of high-bandwidth modular and portable memory devices. In order to ensure security and stability of communication between and within

these devices, Extremely High Frequency (EHF) communications units may be utilized in a variety of new and useful applications.

An EHF communications unit may include one or more EHF communications chip package, or EHF comm-link chip. Examples of such comm-link chips are described in detail in U.S. Provisional Patent Application Ser. Nos. 61/491,811, 61/467,334, 61/485,1103, and 61/485,543, hereby incorporated by reference in their entireties for all purposes.

As shown in FIG. 2, in such EHF communication systems, two EHF comm-link chips must be brought to a certain proximity before the strength of the EHF signal between the comm-link chips is sufficient to establish a stable communication link. As shown in FIG. 2, as the separation distance between two EHF communication components is decreased, signal strength can increase unevenly. Similarly, as the two components are separated, the signal strength decreases unevenly. As a result, the communication system may attempt to create an initial connection only to have it terminate one or more times before becoming established. Similarly, as the components are separated, the connection may terminate, but then immediately attempt to reestablish itself as signal strength increases temporarily.

In order to minimize the impact of such variation in signal strength during the initiation or termination of a contactless EHF connection, each communication package may apply a virtual hysteresis effect during connection and disconnection. A system exhibits hysteresis when the behavior of that system depends not only on its current condition, but also on its immediately previous condition. That is, the behavior of the system during a transition from state A to state B is different than its behavior during a transition from state B to state A. Hysteresis is sometimes described as the lagging of an effect behind its cause.

The imposition of a virtual (or artificial) hysteresis effect on such contactless connections would require that a signal received by a connector must be stronger than a defined minimum signal strength, and exhibit a required degree of stability, before the receiving connector establishes an EHF connection. Conversely, the receiving connector would not terminate the EHF connection between the two connectors until and unless the strength of the received signal dropped below a defined minimum signal strength for a minimum time interval.

Once a virtual hysteresis effect has been imposed, when the two exemplary EHF comm-link chips are brought into proximity, a communication link would not be established until the EHF signal received by the receiving comm-link chip exhibits sufficient strength and/or sufficient strength for a predefined duration. Similarly, as the EHF comm-link chips are separated, the communication link would not be terminated until the EHF signal received by the receiving comm-link dropped below a predefined signal strength. As shown in FIG. 3, this would result in the communication circuit between the comm-link chips to exhibit hysteresis as the communication link is first established, and subsequently terminated.

FIG. 4 is a block diagram showing an illustrative circuit connector 10 according to an embodiment of the present invention. Circuit connector 10 may be capable of implementing a virtual hysteresis loop. The circuit connector 10 includes a receiver 12 configured to receive a transmitted EHF electromagnetic signal; an output circuit 14 coupled to the receiver 12, where the output circuit has two states of operation that correspond to enabling a signal output and disabling the signal output. The circuit connector further

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includes a controller **16** coupled to the receiver **12** and configured to produce a control signal having two states corresponding to a first condition when the received signal exceeds a first threshold and a second condition when the received signal is less than a second threshold. Output circuit **14** is configured to change its state of operation responsive to a state of a control signal.

Alternatively, or in addition, the output circuit **14** of circuit connector **10** may be configured to be responsive to the control signal for outputting an output signal representative of the received signal when the control signal has a first state, and for not outputting the output signal when the control signal has a second state. In this embodiment, the controller is configured to produce the control signal having the second state until a signal strength of the received signal exceeds a first threshold for a first time interval, whereupon the controller produces the control signal having the first state.

FIG. **5** is a block diagram showing an illustrative circuit connector **20** according to an alternative embodiment of the present invention, that may also be capable of implementing a virtual hysteresis loop. Similar to circuit connector **10** of FIG. **4**. The circuit connector **20** includes a receiver **22** configured to receive a transmitted EHF electromagnetic signal **24** from a nearby EHF transmitter **26**, which may be another EHF circuit connector that may be the same or different than device **20**. Receiver **22** may be configured to convert the received modulated EHF electromagnetic signal **24** to a received electronic signal having a received electronic signal level.

Circuit connector **20** may further include an output circuit **28** coupled to the receiver **22**, where the output circuit **28** is responsive to a control signal for enabling a signal output representative of the received signal when the control signal has a first state and for disabling the signal output when the control signal has a second state.

Also coupled to the receiver **22** is a controller **30**. Generally, controller **30** is configured to send a control signal having the second state to the output circuit **28**, preventing the output circuit from enabling signal output until a signal strength of the received signal exceeds a first threshold for a first time interval, at which point the controller **30** sends a control signal having the first state to the output circuit **28**, which responds by enabling a signal output.

Controller **30** may further include a signal strength meter **32** that may be coupled to the receiver **22**, that may be configured to determine a detected signal representative of the electronic signal level received by the receiver **22**. The signal strength meter **32** may be further coupled to a comparison circuit **34** that is configured to compare the detected signal to a threshold signal representative of a first signal strength threshold, and produce a timer control signal indicative of whether or not the detected signal exceeds the threshold signal.

Comparison circuit **34**, in turn, may be coupled to a first timer **36**, that is configured to receive the timer control signal produced by the comparison circuit **34**, and measure a first time interval during which the detected signal exceeds the threshold signal, and output a timer output signal to a control circuit **38**. The control circuit **38** is coupled to both the first timer **36** and to the output circuit **28**, and the control circuit **38** is configured to produce the control signal appropriate for triggering the output circuit **28** to output the received electronic signal in response to the first timer output signal. That is, if the first timer output signal is received by the control circuit **38** from the first timer **36**, the

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detected signal strength has exceeded the threshold signal for the first time interval, and the communication link may therefore be established.

In some embodiments of the invention, the control circuit **38** may include a rate circuit that is configured to calculate a rate of change of the received electronic signal level. By determining the rate of change of the strength of a received electronic signal, the control circuit may determine the difference between the time a signal reaches a lower threshold and the time the signal reaches an upper threshold. A physical device typically always exhibit a rate of closure when establishing a contactless connection, and so if control circuit **38** determines that the lag between the time a signal reaches a lower threshold and the time the signal reaches an upper threshold is less than a predefined reference value, the control circuit may then disable communication of the received electronic signal.

Additionally, circuit connector **20** may further include a second timer **40**. In this embodiment, the output circuit **28** may be configured to prevent the output of the received electronic signal upon receiving a second control signal from control circuit **38**. The comparison circuit **34** may also be additionally configured to compare the detected signal to a second threshold signal representative of a second signal strength threshold, and produce a second timer control signal indicative of whether or not the detected signal fails to meet the second threshold signal. Second timer **40** may be further configured to receive the second timer control signal and measure a second time interval during which the detected signal fails to meet the second threshold signal, and output a second timer output signal to the control circuit **38** that may be representative of whether the detected signal has failed to meet the second threshold signal for the second time interval. In this embodiment of the invention, the control circuit is response to the second timer output signal for producing a second control signal appropriate for preventing the output of the received electronic signal by the output circuit **28** after the detected signal has failed to meet the second threshold for the second time interval. In one embodiment of the invention, the first and second signal strength thresholds are the same, and/or the first and second time intervals are the same.

FIG. **6** is a block diagram showing an illustrative system for implementing a virtual hysteresis loop in an electronic circuit, generally indicated at **50**. Circuit **50** may include a receiver **52** in communication with a transmitter **54** and electrically connected to a demodulator **56**, a low pass filter (LPF) **58** and an amplifier **60**, both electrically connected to demodulator **56**, an enabling circuit **62** disposed electrically between amplifier **60** and a device circuit **64**, and a hysteresis logic circuit generally indicated at **65** electrically connected to both LPF **58** and enabling circuit **62**.

Receiver **52** may be any suitable circuit configured to receive a modulated electromagnetic (EM) signal having an EHF frequency, convert the received signal to an electronic signal, and amplify the signal. The EM signal may be generated by transmitter **54**, which may be located on the same or another device, and/or be in motion relative to the receiver. In some examples, receiver **52** may include an IC package having an embedded antenna and an amplifier. An amplified electronic signal **66** may be communicated to demodulator **56**. Demodulator **56** may be any suitable demodulator component or circuit configured to demodulate signal **66** and to communicate a demodulated signal **67** to both LPF **58** and amplifier **60**. LPF **58** may be any suitable structure or circuit configured to filter demodulated signal **67**

and to generate an averaged signal **68** proportional to the strength of the received signal.

Amplifier **60** may be any suitable component or structure configured to generate a clean output data signal **70**. For example, amplifier **60** may be a comparator configured to compare demodulated signal **67** and averaged signal **68**, and to provide an output data signal **70** that is high when demodulated signal **67** is above averaged signal **68** and low otherwise.

Enable circuit **62** may be any suitable circuit or component configured to selectively block or unblock the connection of output data signal **70** to device circuit **64**. For example, enable circuit **62** may open and close a switch in response to a control signal **72** from hysteresis logic circuit **65**.

Hysteresis logic circuit **65** may include multiple amplifiers each receiving two inputs, one of the inputs being averaged signal **68** and the other being a reference level. Each amplifier may also communicate an output to a respective timer, and the outputs of the amplifiers and/or the timers may be used to logically determine the desired state of enable circuit **62**.

For example, hysteresis logic circuit **65** may include first amplifier **72** and second amplifier **74**. First amplifier **72** may be a comparator that receives inputs **V1** and averaged signal **68**, may compare the two inputs, and may have an output **76** that is high when signal **68** is greater than level **V1**. Second amplifier **74** may be a comparator that receives inputs **V2** and averaged signal **68**, may compare the two inputs, and may have an output **78** that is high when input signal **68** is less than level **V2**.

Signal **76**, in turn, may be provided as an input to a first timer **80** and may initiate first timer **80** when signal **76** is high. Timer **80** may be any suitable component or circuit configured to saturate or terminate at a predetermined amount of time after initiation, and may provide an output **82** that may be high when timer **80** has saturated. Timer output **82** may be provided to a muting logic circuit **84**. Amplifier output **76** may also be provided to muting logic circuit **84**.

Similarly, output signal **68** may be provided to a second timer **86** and may initiate second timer **86** when signal **78** is high. As described above, second timer **86** may time out and provide an output **88** to muting logic circuit **84**, and muting logic circuit **84** may provide a reset input to first timer **80**. In similar fashion, muting logic circuit **84** may provide a reset input to second timer **86**. Amplifier output **78** may also be provided to the muting logic circuit **84**.

Muting logic circuit **84** may be any suitable component or circuit configured to receive multiple inputs, determine a preferred state of enable circuit **62** based on those inputs, and provide controlling signal **90** to enable circuit **64**. For example, muting logic circuit **84** may cause enable circuit **62** to block data signal **70** from reaching device circuit **64** in response to a timed-out signal **88** from second timer **86**.

Turning to FIG. 7, an example of a circuit **50** is depicted and generally indicated at **100**. Circuit **100** may include an antenna **102** electrically connected to an amplifier **104**, which in turn is connected to a demodulator **106** that is in communication with an LPF **108** and a comparator **110**. An output **111** of LPF **108** is also provided to comparators **112** and **114**, which are wired in parallel with each other, and in series with respective timers **116** and **118**. The outputs of first timer **116** and second timer **118** may be provided to control circuit **120**, and an output **122** of control circuit **120** may be provided, along with an output **124** of comparator **110**, to a logic AND gate **126**.

In this example, as in the description above regarding circuit **50**, a received signal is processed through antenna **102**, amplifier **104**, and demodulator **106** and filtered by LPF **108**. A baseband data signal **124** is generated by running the received signal (and possibly a filtered signal **111**) through comparator **110** or any other suitable component or circuit. In this example, filtered signal **111** is compared to a first threshold voltage $V_{th}(1)$ by comparator **112** and to a second threshold voltage $V_{th}(2)$ by comparator **114**, where the first threshold voltage and second threshold voltage may be the same or different. As shown in FIG. 7, $V_{th}(1)$ may be provided to a negative input of comparator **112**, and $V_{th}(2)$ may be provided to a positive input of comparator **114**, with signal **111** on the remaining respective inputs. Accordingly, comparator **112** will provide a high output and start first timer **116** when signal **111** is greater than $V_{th}(1)$, and comparator **114** will provide a high output and start second timer **118** when signal **111** is less than $V_{th}(2)$.

Timers **116** and **118** each may have user-selectable timer settings and may time out, or saturate, at different durations. Upon saturation, an output of each timer may go high. Because each timer output is communicated to control circuit **120**, an output **122** of control circuit **120** may be changed depending on the state of each timer. For example, output **122** may be high when first timer **116** is saturated and second timer **118** is not saturated, and may be low when second timer **118** is saturated and first timer **116** is not saturated. Furthermore, the outputs of timers **116** and **118**, or signals based on a state of those outputs, may each be used by control circuit **120** to reset the other timer. This may be done, for example, to ensure that both timers are not simultaneously in a saturated state. In some examples, logic circuit **120** may reset either or both timers based on these or other criteria.

In some examples, timer **116** and/or timer **118** may begin timing upon receiving a high output signal from a respective comparator, and may continue timing out only as long as the high signal is received, resetting to zero if a terminal count is not reached. This method may be referred to as "episodic" in that it keeps track of time above or below a threshold for that particular episode or excursion above or below. In other examples, timer **116** and/or timer **118** may begin incrementing upon receipt of a high signal from a respective comparator, but may then decrement upon receipt of a low signal from the comparator. In these examples, timing may only include positive values, meaning a timer may not go negative but may instead stop at a zero, or reset condition. Accordingly, in these examples, the timer or timers may reflect a cumulative time above or below a threshold value over several episodes, rather than a single episode above or below a threshold value.

Because AND gate **126** requires that both signal **124** and signal **122** be present before providing an output **128**, control circuit **120** and AND gate **126** may provide the functions of muting circuit **72** and enable circuit **62** as previously described.

Turning to FIG. 8, a flow chart **130** is provided showing an illustrative sequence of events when using a representative circuit such as circuit **100**, including episodic timers as described above. In this example, beginning at reference numeral **132**, a signal may be received and its strength measured at **134**. If that measured strength is less than a first threshold as determined at **136**, a first timer is reset at **138**, and the measuring and monitoring of the received signal continues at **132** and **134**. If the measured strength is greater than the first threshold, a first timer is advanced at **140**. If, after advancing the first timer, the first timer reaches a

terminal count (i.e., times out) at **142**, an output of the circuit is unmuted at **144**. As described above, this output may be the baseband data signal of a received signal. In this example, a second timer B may be reset at **146** simultaneously or sequentially with the unmuting of the output signal.

Once the output signal has been unmuted, the received signal strength continues to be measured at **148**. If the signal strength is at or above the second threshold, the second timer B is reset at **146**, but if the signal strength falls below the second threshold level at **150**, the second timer is advanced at **152**. If the second timer reaches its terminal count (i.e., times out) at **154**, the output is then muted at **156** and the first timer may be simultaneously reset in preparation for the signal strength again possibly rising above the first threshold. As is shown by flowchart **130**, this process of measuring signal strength over time may be an ongoing process, continuing ad infinitum.

FIG. **9** provides a flowchart **160** that shows an illustrative sequence of events when using a circuit such as representative circuit **100**, this time with incrementing and decrementing timers as described above. Beginning at reference numeral **162**, a signal may be received and its strength measured at **164**. If that measured strength is less than a first threshold, as determined at **166**, a first timer is decremented at **168** and measuring and monitoring of the received signal continues at **162**. If the first timer is decremented until it reaches zero, it will not be decremented further. In other words decrementing will not continue below the reset value. If the measured strength is greater than the first threshold, as determined at **166**, the first timer is incremented at **170**. If by incrementing the first time, the timer reaches a terminal count (i.e., times out) at **172**, an output of the circuit is unmuted at **174**. In this example, a second timer may be reset at **176** simultaneously or sequentially with the unmuting of the output signal.

The unmuted signal is received at **178** and continues to be measured at **180**. If the signal strength is above a certain second threshold level as determined at **182**, the second timer is decremented at **184**. Similar to the first timer, the second timer will not be decremented below a zero or reset value. Alternatively, if the received signal strength is below the second threshold, the second timer will be incremented at **186**. If the second timer reaches its terminal count (i.e., times out) at **188**, the output is then muted at **190** and the first timer may be simultaneously or sequentially reset at **192** in preparation for the signal strength again possibly rising above the first threshold. Similar to the flowchart **130** of FIG. **8**, this sequence of operations may continue indefinitely.

FIG. **10** illustrates how a hysteresis circuit, such as exemplary circuit **100** may respond to a received EHF electromagnetic signal that is intermittently increasing as the separation distance between the components of the connection is steadily decreased. Although the details of FIG. **10** are representative and exemplary, the signal strength between a transmitter and receiver is generally inversely proportional to the separation distance between them. Line **200** represents the signal strength of a received signal. Signal strength **200** increases until the strength of the signal reaches a first threshold **202** at point **204**. The hysteresis circuit then begins incrementing a first timer and continues to monitor the signal strength. After a time interval **206** the signal strength falls below threshold **202** at point **208**. Since the time interval **206** is less than a preselected minimum required duration **210**, the first timer is reset.

Signal strength **200** then increases again and at point **212** the signal strength passes threshold level **202** and the

hysteresis circuit begins incrementing the first timer. Thereafter, signal strength **200** remains continuously above the minimum signal level **202** until the first timer reaches its terminal count, resulting in time interval **210**, and the received signal is unmuted and a connection is established, as indicated by line **214** which depicts the state of the connection.

Conversely, FIG. **11** illustrates how the hysteresis circuit **100** would respond to a connected EHF electromagnetic signal that is decreasing as the separation distance between the components of the connection is steadily increased. Line **220** represents the signal strength of a received signal. Signal strength **220** decreases until the strength of the signal drops below a second threshold **222** at point **224**. The hysteresis circuit then begins incrementing a second timer and continues to monitor the signal strength. After a time interval **226** the signal strength rises above threshold **222** at point **228**. Since the time interval **226** is less than a preselected minimum duration, the second timer is reset.

Signal strength **220** then begins to decrease again and at point **228** the signal strength again drops below threshold level **222**. Thereafter, signal strength **220** remains continuously below the minimum signal level **222** until the second timer reaches its terminal count after time interval **230**, and the received signal is muted and the connection is terminated, as indicated by line **232** which depicts the state of the connection. Although signal strength **220** again increases above threshold level **222** at **234**, the second timer has been reset and this has no effect.

Considering the examples provided in FIGS. **8** and **9**, FIGS. **10** and **11** may depict the end result of the application of a hysteresis circuit such as circuit **100** by the components of a contactless EHF connection. As shown, line **212** of FIG. **10** depicts the formation of the contactless connection as the separation distance between the two components of the connection is decreased. Because of the effect of the hysteresis circuit, the connection is not established until the signal strength between the two components is both strong and stable. Line **232** of FIG. **11** depicts the termination of the contactless connection as the separation distance between the two components of the connection is increased. Again, due to the effect of the applied virtual hysteresis, the connection is not terminated until signal strength is consistently lower than desirable. The occurrence of transient connections thereafter is prevented, because the signal strength must increase to the first threshold before the first timer is even activated.

In one embodiment of the invention, the devices and systems of the present invention lend themselves to a method for establishing an electronic signal using a circuit connector configured to communicate via EHF electromagnetic signals, as depicted in flowchart **240** of FIG. **12**. The exemplary method includes receiving an EHF electromagnetic signal at the circuit connector at **242**; converting the received EHF electromagnetic signal to a received electronic signal having a received electronic signal level at **244**; detecting a signal representative of the received electronic signal level at **246**; comparing the detected signal to a threshold signal representative of a first signal strength threshold at **248**; initiating a first timer when the detected signal exceeds the threshold signal at **250**; measuring a first time interval during which the detected signal exceeds the threshold signal at **252**; outputting a first timer output signal when the detected signal exceeds the first signal strength threshold for the first time interval at **254**; and outputting the received electronic signal in response to the first timer output signal at **256**.

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In addition, the method of flowchart **240** may optionally further include the additional elements set out at flowchart **260** of FIG. **13**. Flowchart **260** includes comparing the detected signal to a second threshold signal representative of a second signal strength threshold at **262**; initiating a second timer if the detected signal fails to meet the second threshold signal at **264**; measuring a second time interval during which the detected signal fails to meet the second threshold signal at **266**; outputting a second timer output signal when the detected signal fails to meet the second threshold signal for a second time interval at **268**; and preventing an output of the received electronic signal in response to the second timer output signal at **270**.

Alternatively, the method of flowchart **240** may optionally further include the additional elements set out at flowchart **272** of FIG. **14**. Flowchart **272** includes resetting the second timer in response to the detected signal meeting the second threshold signal at **274**; outputting the second timer output signal when the detected signal fails to meet the second threshold signal for the second time interval at **276**; and preventing the output of the received electronic signal in response to the second timer output signal at **278**.

In yet another embodiment of the invention, the devices and systems of the present invention lend themselves to a method for establishing a contactless EHF electromagnetic connection between a first and second device configured to communicate via EHF electromagnetic signals. FIG. **15** depicts a block diagram **280** depicting another exemplary method for implementing a hysteresis function in an electronic circuit. The method may include receiving a modulated electromagnetic (EM) signal at **282**; converting the EM signal to a received electronic signal at **284**; demodulating the received electronic signal at **286**, passing the received electronic signal through a low pass filter to generate an averaged signal proportional to a signal strength of the received electronic signal at **288**; comparing the averaged signal to a first reference at **290**; and enabling communication of the received electronic signal to a device circuit in response to the averaged signal remaining above the first reference for a first amount of time at **292**.

The method of block diagram **280** may optionally further include comparing the averaged signal to a second reference at **294**; and disabling communication of the received electronic signal to the device circuit in response to the averaged signal remaining below the second reference for a second amount of time at **296**.

In some aspects of the present invention, it may be desirable to determine a speed at which a received signal is changing strength. For example, such a determination may be desirable as a security method to ensure that electronic spoofing is not occurring. As physical devices have some real rate of closure when establishing a contactless connection, there should be a measurable difference between the time a signal reaches a lower threshold and the time the signal reaches an upper threshold. The method of block diagram **280** may further include determining a duration between a time the averaged signal reaches the second reference and a time the averaged signal reaches the first reference at **298**; and disabling communication of the received electronic signal in response to the duration being less than a third reference at **300**.

It is believed that the disclosure set forth herein encompasses multiple distinct inventions with independent utility. While each of these inventions has been disclosed in its preferred form, the specific embodiments thereof as disclosed and illustrated herein are not to be considered in a limiting sense as numerous variations are possible. Each

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example defines an embodiment disclosed in the foregoing disclosure, but any one example does not necessarily encompass all features or combinations that may be eventually claimed. Where the description recites "a" or "a first" element or the equivalent thereof, such description includes one or more such elements, neither requiring nor excluding two or more such elements. Further, ordinal indicators, such as first, second or third, for identified elements are used to distinguish between the elements, and do not indicate a required or limited number of such elements, and do not indicate a particular position or order of such elements unless otherwise specifically stated.

What is claimed is:

1. A first contactless connector included in a first device for communicating with a second contactless connector included in a second device using extremely high frequency (EHF) signals, the first contactless connector comprising:

a receiver configured to receive a transmitted EHF electromagnetic signal from the second contactless connector;

a low-pass filter connected to the receiver and configured to generate an averaged signal proportional to a strength of the transmitted EHF signal;

an enable circuit configured to receive the transmitted EHF signal from an output of the low pass filter, the enable circuit configured to output the transmitted EHF signal when a control signal has a first state and configured to not output the transmitted EHF signal when the control signal has a second state; and

a hysteresis logic circuit connected to the low-pass filter and the enable circuit, the hysteresis logic circuit configured to:

produce the control signal having the second state until the determined signal strength of the averaged signal exceeds a first threshold for a first time interval, whereupon the controller produces the control signal having the first state to enable the enable circuit to output the transmitted EHF signal from the receiver; and thereafter

produce the control signal with the second state to disable the enable circuit from outputting the transmitted EHF signal from the receiver when the determined signal strength of the averaged signal fails to meet a second threshold for a second time interval.

2. The first contactless connector of claim **1**, further comprising a demodulator coupled between the receiver and the low pass filter and configured to demodulate the received signal.

3. The first contactless connector of claim **2**, further comprising an amplifier coupled between the low pass filter and the enable circuit, wherein the amplifier compares a demodulated signal from the demodulator with the averaged signal to determine an output signal to provide to the enable circuit.

4. The first contactless connector of claim **1**, wherein the first and second thresholds are the same, and the first and second time intervals are the same.

5. The first contactless connector of claim **1**, wherein the first threshold is greater than the second threshold.

6. The first contactless connector of claim **1**, wherein the hysteresis logic circuit comprises:

a first comparator connected to the low-pass filter and configured to compare the averaged signal with a first reference level corresponding to the first threshold;

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a second comparator connected to the low-pass filter and configured to compare the averaged signal with a second reference level corresponding to the second threshold;

a first timer connected to the first comparator configured to determine whether the averaged signal exceeds the first threshold for the first time interval;

a second timer connected to the second comparator configured to determine whether the averaged signal fails to meet the second threshold for the second time interval;

a muting logic circuit connected to the first timer and the second timer, the muting logic circuit configured to determine a state of the control signal based on one or more timer signals received from the first and second timers, the muting logic circuit further configured to produce the control signal with the determined state.

7. The first contactless connector of claim 6, wherein the muting logic circuit is configured to reset the first timer if the determined signal strength drops below the first signal strength threshold during the first time interval.

8. The first contactless connector of claim 6, wherein the muting logic circuit is configured to reset the second timer when the first timer reaches the end of the first time interval.

9. The first contactless connector of claim 6, wherein the muting logic circuit is configured to reset the first timer when the second timer reaches the end of the second time interval.

10. The first contactless connector of claim 1, wherein the first signal strength threshold and the first time interval are user-selectable.

11. The first contactless connector of claim 1, wherein the receiver includes an integrated circuit package having an antenna embedded in the package and configured to receive the transmitted EHF electromagnetic signal.

12. A first contactless connector included in a first device for communicating with a second contactless connector included in a second device using extremely high frequency (EHF) signals, the first contactless connector comprising:

a receiver configured to receive a transmitted EHF electromagnetic signal from the second contactless connector;

an output circuit coupled to receive the transmitted EHF signal from an output of the receiver, the output circuit configured to:

output the transmitted EHF signal when a control signal has a first state and configured to not output the transmitted EHF signal when the control signal has a second state; and

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a controller coupled to the receiver and configured to: determine a signal strength of the transmitted EHF signal;

increment a first timer responsive to determining that the determined signal strength is above a first threshold;

produce the control signal having the second state until the first timer reaches a first terminal count, whereupon the controller produces the control signal having the first state to enable the output circuit to output the transmitted EHF signal from the receiver;

increment a second timer responsive to determining that the determined signal strength is below a second threshold; and

produce the control signal with the second state to disable the output circuit from outputting the transmitted EHF signal from the receiver when the second timer reaches a second terminal count.

13. The first contactless connector of claim 12, wherein the controller is configured to decrement the first timer responsive to determining that the determined signal strength is not above the first threshold.

14. The first contactless connector of claim 12, wherein the controller is configured to decrement the second timer responsive to determining that the determined signal strength is not below a second threshold.

15. The first contactless connector of claim 12, wherein the first and second thresholds are the same, and the first and second terminal counts are the same.

16. The first contactless connector of claim 12, wherein the first threshold is greater than the second threshold.

17. The first contactless connector of claim 12, wherein the first signal strength threshold and the first terminal count are user-selectable.

18. The first contactless connector of claim 12, wherein the receiver includes an integrated circuit package having an antenna embedded in the package and configured to receive the transmitted EHF electromagnetic signal.

19. The first contactless connector of claim 12, wherein producing the control signal having the first state to enable the output circuit to output the transmitted EHF signal from the receiver further comprises resetting the second timer.

20. The first contactless connector of claim 12, wherein producing the control signal with the second state to disable the output circuit from outputting the transmitted EHF signal from the receiver further comprises resetting the first timer.

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