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(54) **RECEIVE ATTENUATION SYSTEM FOR TRAINLINE COMMUNICATION NETWORKS**

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See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

3,093,802 A 6/1963 Chow
4,012,603 A 3/1977 Araseki et al.
4,383,243 A 5/1983 Krugel et al.
(Continued)

FOREIGN PATENT DOCUMENTS

DE 421 4821 11/1992
DE 195 01 887 7/1995
(Continued)

OTHER PUBLICATIONS

International Search Report re PCT/US2014/051637 mailed Nov. 26, 2014.
(Continued)

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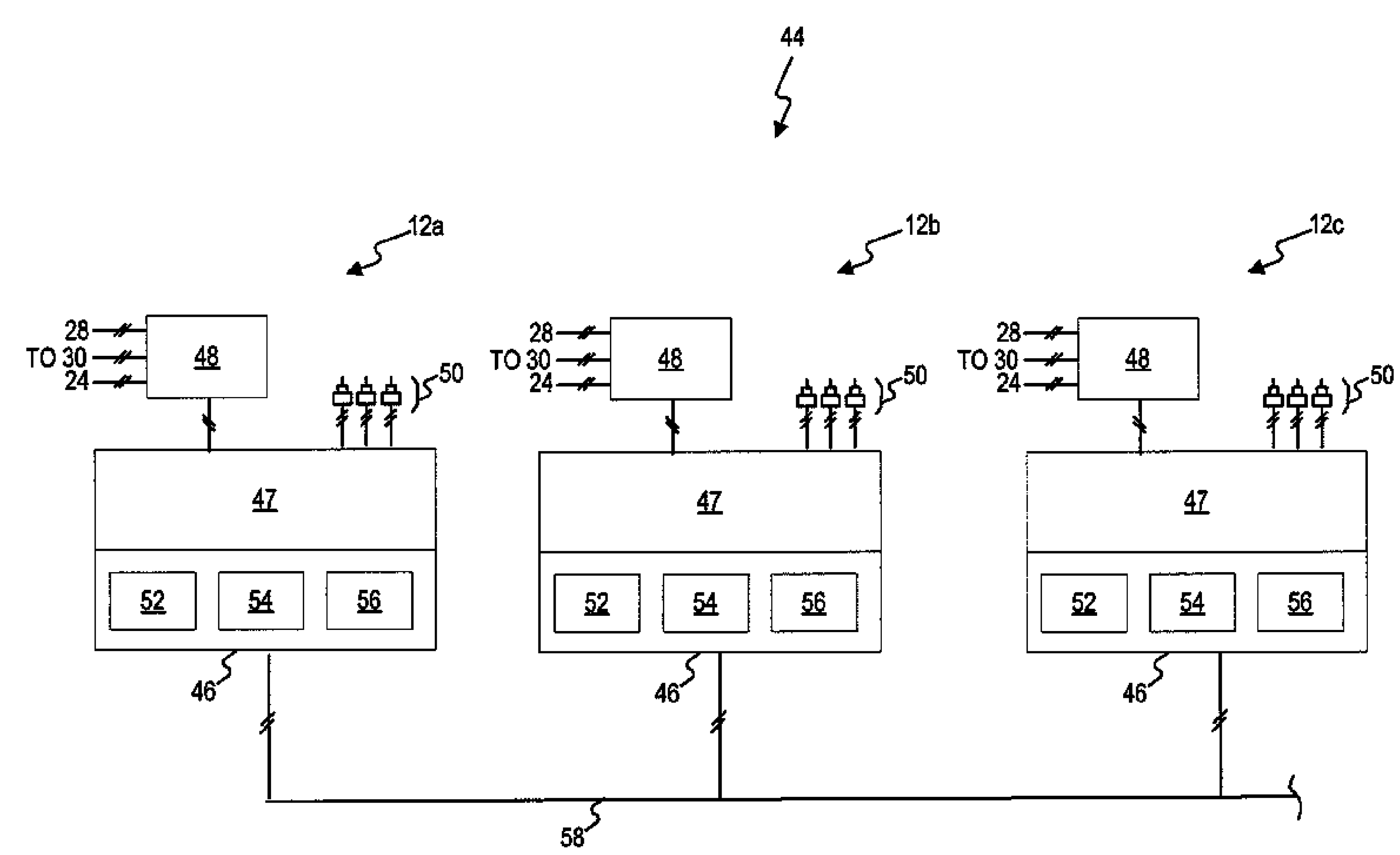
(57) **ABSTRACT**

A receive attenuation system for a trainline communication system utilizing an intra-consist electrical cable has an analog front end amplifier, a trainline communication processor, an adjustable attenuator, and a gain controller. The trainline communication processor is configured to generate a receive gain control signal configured to control receive gain of the analog front end amplifier. The adjustable attenuator is capable of being coupled to the intra-consist electrical cable and configured to variably attenuate signals received from the intra-consist electrical cable before transmitting the signals to the analog front end amplifier. The gain controller is coupled to the adjustable attenuator and configured to detect the receive gain control signal generated by the trainline communication processor, determine a supplemental attenuation control value based on the detected receive gain control signal, and control the adjustable attenuator according to the supplemental attenuation control signal.

20 Claims, 4 Drawing Sheets



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(56) **References Cited**

U.S. PATENT DOCUMENTS

4,556,866	A	12/1985	Gorecki
4,578,818	A	3/1986	Claydon
4,721,923	A	1/1988	Bares et al.
4,724,396	A	2/1988	Taylor, Jr. et al.
4,815,106	A	3/1989	Propp et al.
4,860,308	A	8/1989	Kamerman et al.
5,351,272	A	9/1994	Abraham
5,446,918	A	8/1995	Lamy
5,651,517	A	7/1997	Stevens et al.
5,706,191	A	1/1998	Bassett et al.
5,717,685	A	2/1998	Abraham
5,777,545	A	7/1998	Patel et al.
5,777,547	A	7/1998	Waldrop
5,818,127	A	10/1998	Abraham
5,969,643	A	10/1999	Curtis
5,986,577	A	11/1999	Bezos
6,114,974	A	9/2000	Halvorson
6,163,089	A	12/2000	Kull
6,311,045	B1	10/2001	Domokos
6,373,375	B1	4/2002	Hoetzel et al.
6,392,368	B1	5/2002	Deller et al.
6,392,562	B1	5/2002	Boston et al.
6,408,766	B1	6/2002	McLaughlin et al.
6,421,587	B2	7/2002	Diana et al.
6,442,195	B1	8/2002	Liu et al.
6,490,523	B2	12/2002	Doner
6,553,838	B2	4/2003	Amini
6,567,648	B1	5/2003	Ahn et al.
6,587,739	B1	7/2003	Abrams et al.
6,595,045	B1	7/2003	Fuglewicz et al.
6,972,670	B2	12/2005	LaDuc et al.
6,995,658	B2	2/2006	Tustison et al.
7,006,523	B2	2/2006	Binder
7,021,588	B2	4/2006	Hess, Jr. et al.
7,113,752	B2	9/2006	Leinonen et al.
7,182,411	B2	2/2007	Levy et al.
7,206,320	B2	4/2007	Iwamura
7,336,156	B2	2/2008	Arita et al.
7,499,682	B2	3/2009	Rozenblit et al.
7,634,240	B2	12/2009	Mitzlaff et al.
7,893,557	B2	2/2011	Davis et al.
7,933,420	B2	4/2011	Copley et al.
8,036,402	B2	10/2011	Furge
8,068,616	B2	11/2011	Copley et al.
8,140,027	B2	3/2012	Ozgun et al.
8,160,520	B2	4/2012	Srinivasan et al.
8,232,666	B2	7/2012	Rocamora et al.
8,305,229	B1	11/2012	Gard
8,306,489	B2	11/2012	Schwarzmueller et al.
8,340,318	B2	12/2012	Copley et al.
8,364,189	B2	1/2013	Mintah et al.
8,447,255	B2	5/2013	Asokan
2002/0011923	A1	1/2002	Cunningham et al.
2002/0101882	A1	8/2002	Kim
2002/0167398	A1	11/2002	Strasser
2003/0195668	A1	10/2003	Radtke et al.
2004/0223275	A1	11/2004	Yanagida et al.
2004/0261101	A1	12/2004	Iwamura
2005/0013320	A1	1/2005	Binder
2005/0085259	A1	4/2005	Conner et al.
2005/0143868	A1	6/2005	Whelan
2006/0025903	A1	2/2006	Kumar
2006/0170285	A1	8/2006	Morimitsu et al.
2007/0136050	A1	6/2007	Tourwe
2007/0282494	A1	12/2007	Moffitt et al.
2007/0286079	A1	12/2007	Mollenkopf et al.
2008/0003962	A1	1/2008	Ngai
2008/0195259	A1	8/2008	Davis et al.
2008/0211663	A1	9/2008	Mansfield et al.
2008/0291983	A1	11/2008	Myers
2008/0298384	A1	12/2008	Beaucage
2009/0042436	A1	2/2009	Emoto et al.
2009/0287496	A1	11/2009	Thyssen et al.
2010/0045447	A1	2/2010	Mollenkopf et al.
2010/0235022	A1	9/2010	Siddappa et al.
2010/0241295	A1 *	9/2010	Cooper et al. 701/19
2010/0256842	A1	10/2010	Liberatore
2011/0093144	A1	4/2011	Goodermuth et al.
2012/0095580	A1	4/2012	Zhang
2012/0163201	A1	6/2012	Williams et al.
2012/0237010	A1	9/2012	Hurwitz
2013/0038424	A1	2/2013	Katar et al.
2013/0077801	A1	3/2013	Tarnowski
2013/0271342	A1	10/2013	Shen
2013/0320154	A1	12/2013	Brown
2013/0323939	A1	12/2013	Brown
2014/0033943	A1	2/2014	Foege et al.
2014/0153380	A1	6/2014	Luecke et al.
2014/0353434	A1	12/2014	Otsubo et al.
2014/0358336	A1	12/2014	Otsubo et al.

FOREIGN PATENT DOCUMENTS

DE	100 44 088	4/2002
DE	202007008825	8/2007
EP	0 968 897	1/2000
EP	1 010 602	6/2000
EP	1 065 127	1/2001
EP	1 253 725	10/2002
EP	1 306 283	5/2003
EP	1 487 128	12/2004
GB	109 7125	12/1967
GB	2 450 520	12/2008
JP	7508609	9/1995
JP	11/317697	11/1999
JP	2004/235752	8/2004
JP	2004/241997	6/2005
JP	2005/176131	6/2005
JP	4906002	3/2012
KR	10-0899228	5/2009
WO	WO 94/01949	1/1994
WO	WO 2004/054224	6/2004
WO	WO 2006/075767 A3	7/2006

OTHER PUBLICATIONS

Amirshahi, Pouyan, et al., "High-Frequency Characteristics of Overhead Multiconductor Power Lines for Broadband Communications," IEEE Journal on Selected Areas in Communications, vol. 24, No. 7, Jul. 2006, p. 1292.

Carcelle, Xavier, "Power Line Communications in Practice," Hybrid PLC (2009), p. 304.

Dai, Huaiyu, et al., "Advanced Signal Processing for Power Line Communications," *IEEE Communications Magazine*, May 2003, p. 100.

Hailes, S., "Modern telecommunications systems for train control," The 11th IET Professional Development Course on Railway Signalling and Control Systems, Jun. 2006, pp. 185-192.

IEEE Standard for Communications Protocol Aboard Trains, IEEE Std 1473-1999.

Kamata, Keiichi, "T-Ethernet: The Next International Standard Candidate for Train Communication Network." 2008.

Kirrmann, Hubert, et al., "The IEC/IEEE Train Communication Network," IEEE (2001).

Liu, Er, et al., "Broadband Powerline Channel and Capacity Analysis," IEEE (2005) p. 7.

Liu, Er, et al., "Powerline Communication Over Special Systems," IEEE (2005), p. 167.

"Nexans signaling cable enhances," *Railway Gazette International*; Apr. 2006; 162, 4; ProQuest, p. 206.

PM4380 Analog Front End for VDSL2/ADSL2+, Preliminary Product Brief, PMC-2060187, Issue 3, PMC-Sierra, Inc. (2007).

Roden, Andrew, "Duotrack signals S&T cabling revolution," *International Railway Journal*; Jul. 2007; 47, 7; ABI/INFORM Complete, p. 38.

(56) **References Cited**

OTHER PUBLICATIONS

Russo, D., et al., "A New Approach for Train Passenger Information Systems," presented at WCRR 2008 Seoul Korea, May 18-22, 2008.

Swanson, John D., "Advanced Light Rail Vehicle Communication Systems Design," Proceedings of the 2004 ASME/IEEE Joint Rail Conference, Apr. 6-8, 2004, p. 213.

Trainline communications—trainline communication system specifications—Vehicle Track Systems Newletter, *Railway Age*, Dec. 1994.

Latchman et al., "Homeplug AV and IEEE 1901: A Handbook for PLC Designers and Users," Mar. 18, 2013, IEEE Press, p. 316.

U.S. Appl. No. 14/250,613 by Neil Keith Habermehl et al., filed Apr. 11, 2014, entitled "Train Communication Network.".

U.S. Appl. No. 14/250,586 by Neil Keith Habermehl et al., filed Apr. 11, 2014, entitled "Train Communication Network.".

U.S. Appl. No. 14/250,641 by Neil Keith Habermehl et al., filed Apr. 11, 2014, entitled "Train Communication Network.".

* cited by examiner

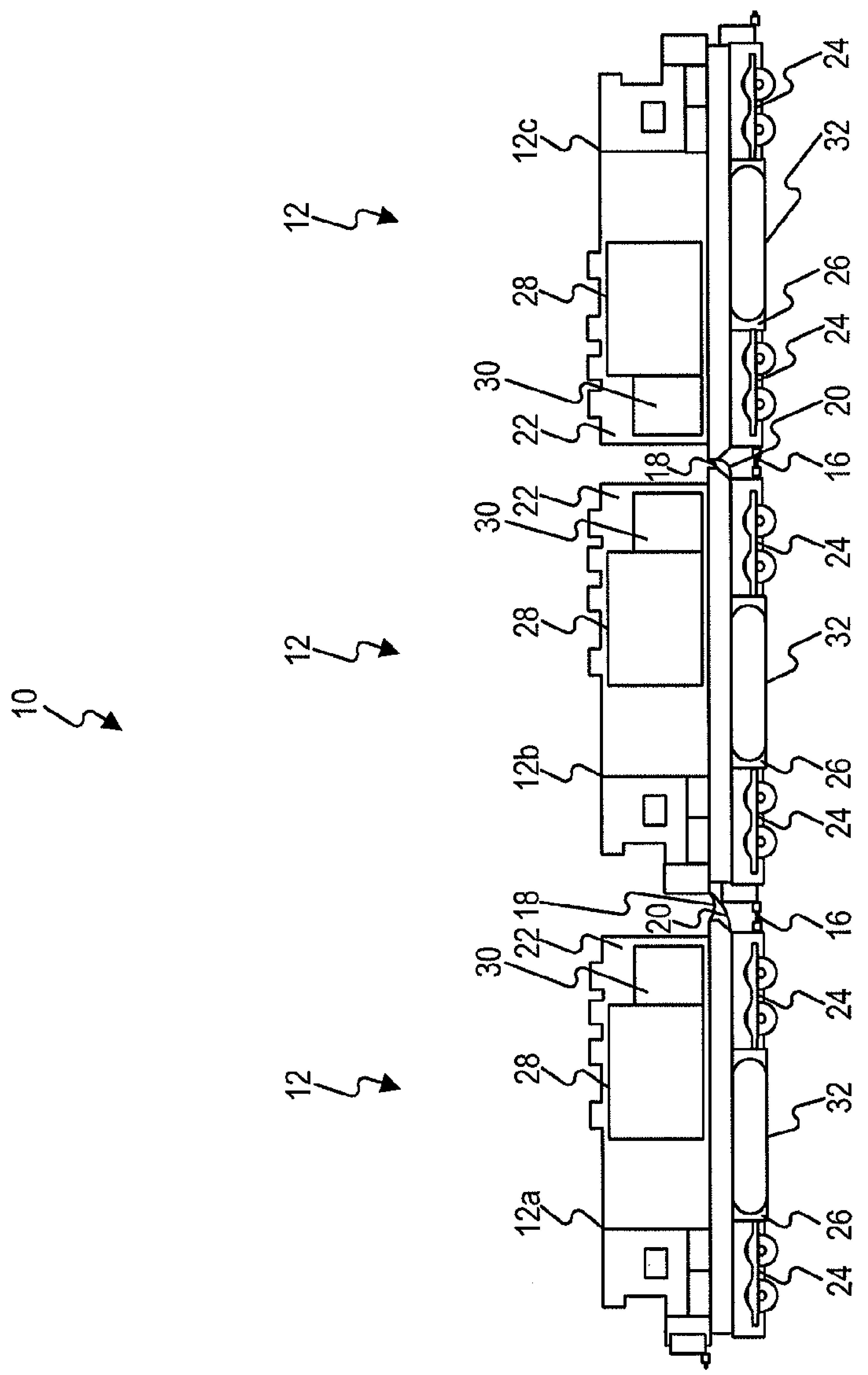

FIG. 1

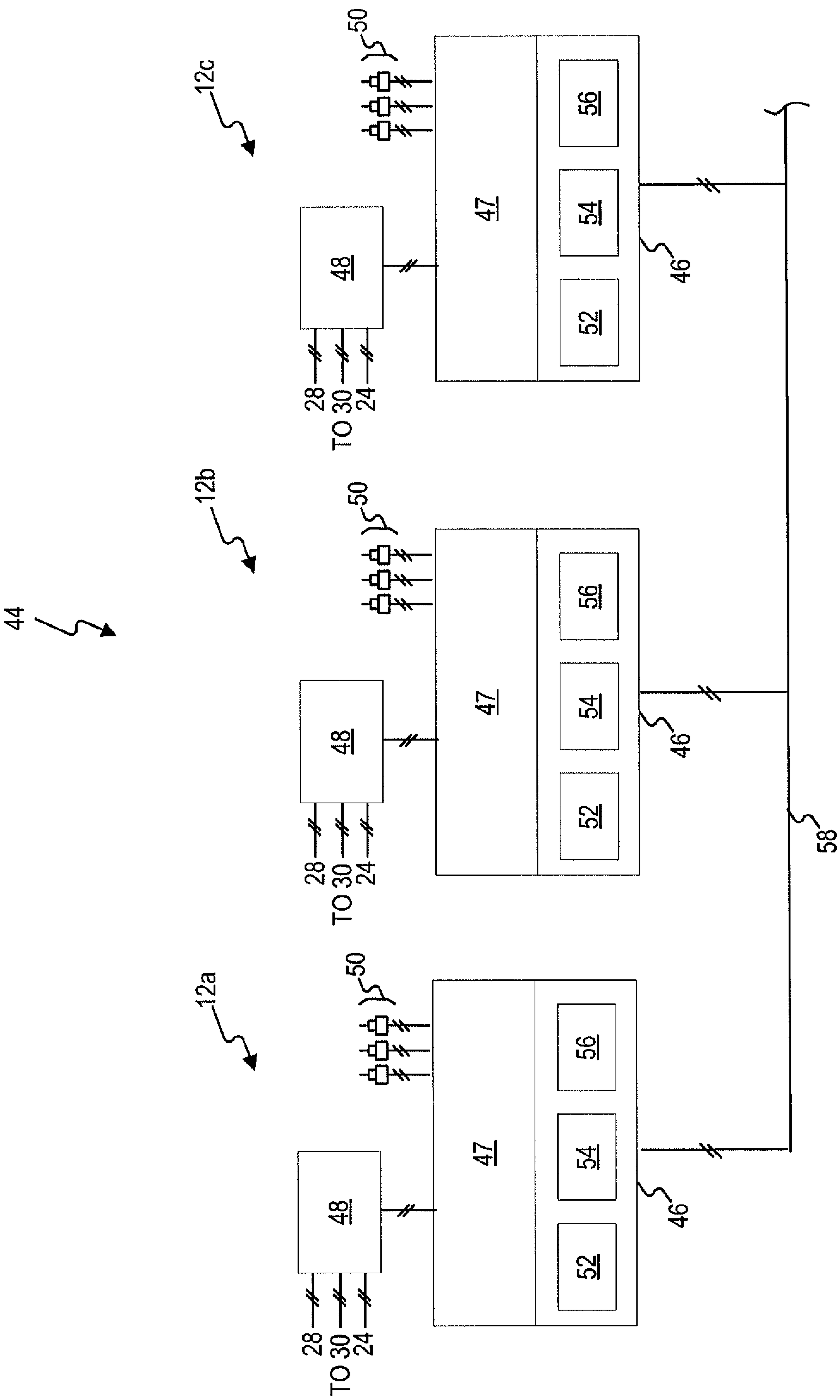

FIG. 2

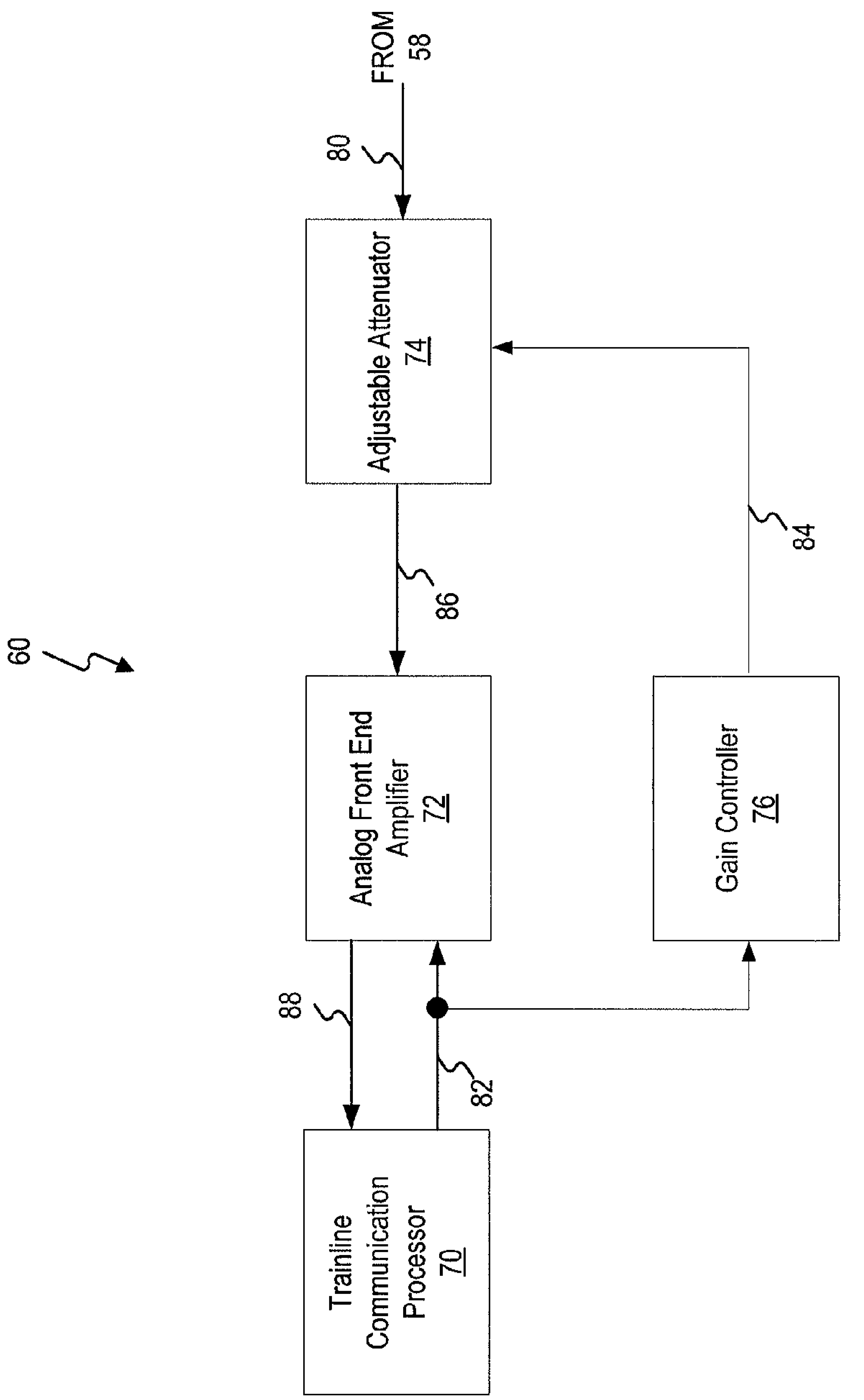
FROM 58
80
Adjustable Attenuator 74
84
86
60
Analog Front End Amplifier 72
Gain Controller 76
88
82
Trainline Communication Processor 70

FIG. 3

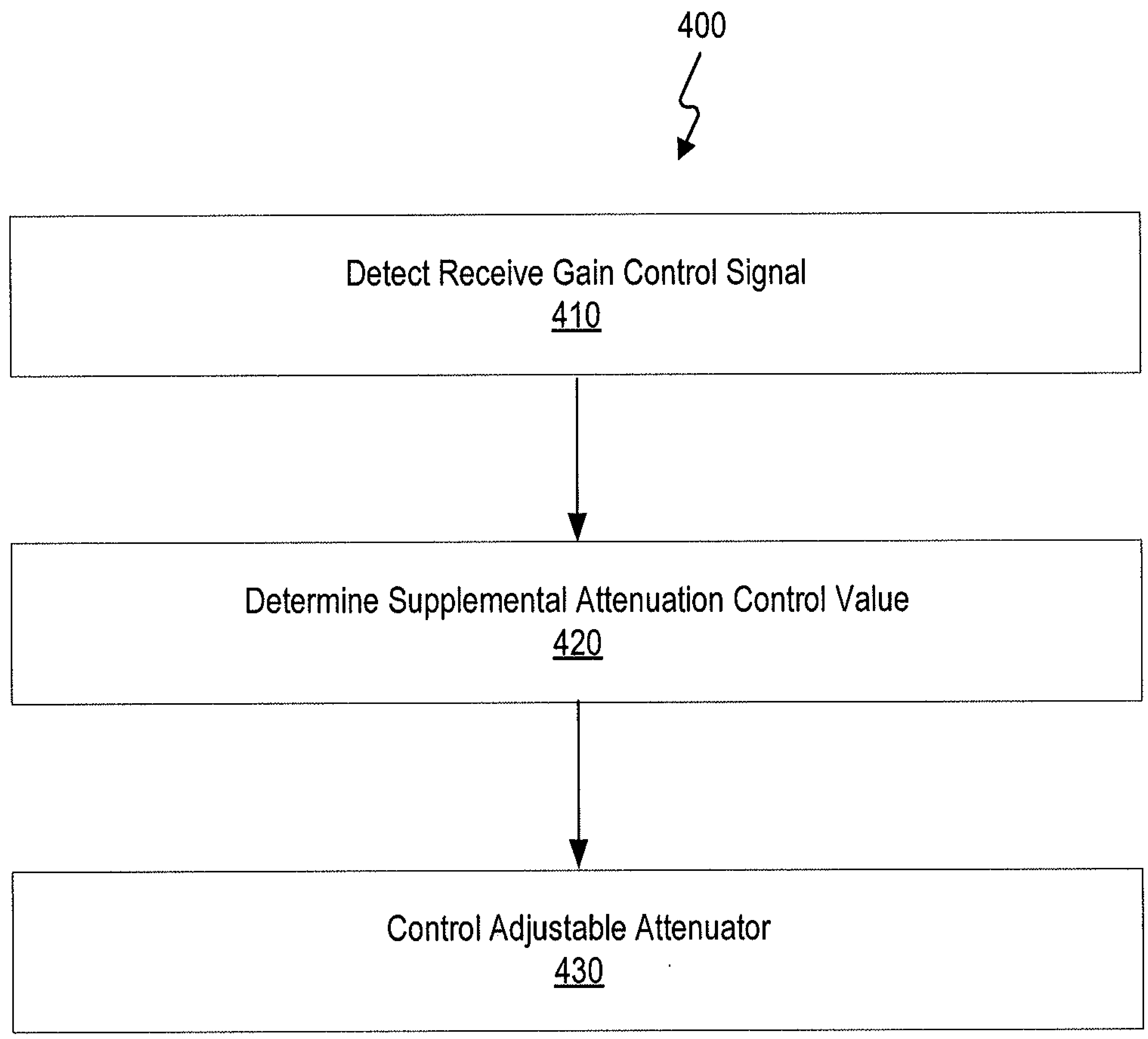
400
Detect Receive Gain Control Signal
410
Determine Supplemental Attenuation Control Value
420
Control Adjustable Attenuator
430

FIG. 4

RECEIVE ATTENUATION SYSTEM FOR TRAINLINE COMMUNICATION NETWORKS

TECHNICAL FIELD

The present disclosure relates generally to a trainline communications network, and more particularly, to a receive attenuator for a trainline communication network.

BACKGROUND

A consist includes one or more locomotives that are coupled together to produce motive power for a train of rail vehicles. The locomotives each include one or more engines, which combust fuel to produce mechanical power. The engine(s) of each locomotive can be supplied with liquid fuel (e.g., diesel fuel) from an onboard tank, gaseous fuel (e.g., natural gas) from a tender car, or a blend of the liquid and gaseous fuels. The mechanical power produced by the combustion process is directed through a generator and used to generate electricity. The electricity is then routed to traction motors of the locomotives, thereby generating torque that propels the train. The locomotives can be connected together at the front of the train or separated and located at different positions along the train. For example, the consist can be positioned at the front, middle, or end of the train. In some instances, more than one consist can be included within a single train. In some consists, the locomotives include computer systems for maintaining operations of the locomotive.

Because the locomotives of a consist must cooperate to propel the train, communication between the locomotives can be important. Historically, this communication has been facilitated through the use of an MU (Multi-Unit) cable that extends along the length of the consist. An MU cable is comprised of many different wires, each capable of carrying a discrete signal used to regulate a different aspect of consist operation. For example, a lead locomotive generates current within a particular one of the wires to indicate a power level setting requested by the train operator. When this wire is energized, the engines of all trailing locomotives are caused to operate at a specific throttle value. In another example, when one locomotive experiences a fault condition, another of the wires is energized to alert the other locomotives of the condition's existence.

In some consists, locomotives communicate via their respective computer systems on an Ethernet network formed over the MU cables, or other intra-consist electrical cables. With this configuration, network data can be transmitted from the computer system in the lead locomotive to the computer systems in the trail locomotives, and vice-versa. The network data includes data that is packaged as data packets and uniquely addressed to particular computer systems, or portions of the computer systems. The network data can be, for example, vehicle sensor data indicative of vehicle health, commodity condition data, temperature data, weight data, and security data. The network data is transmitted orthogonal to conventional non-network (i.e., command) data that is already being transmitted on the MU cable.

Traditionally, communication over a MU cable or other intra-locomotive cable was limited to voltage levels for individual wires within the MU cable. For example, a high voltage applied to an individual wire might indicate one value, while a low or zero voltage applied to the individual wire might indicate a second value. While MU cables provide an existing infrastructure that can be used by the computer systems of locomotives to communicate network data, MU cables were not designed for network data communication. For example, the wires within a MU cable are not shielded or twisted and are subject to interference. As a result, signal strength can degrade significantly as the signal propagates the length of a MU cable. For example, in a locomotive consist, the locomotive computer system adjacent to the signal's origin might receive the signal at 10 dBm, a locomotive further away in the consist might receive the signal at −30 dBm, which may be too weak to effectively transmit network data.

The signal degradation can be overcome by increasing strength of the signal when it is transmitted. While increasing the transmit signal allows for adequate signal strength to reach locomotive computer systems far away from the origin of the signal, it can overload the components of locomotive computer systems that are located close to the origin of the signal. For example, increasing the signal strength might produce a received 10 dBm signal at a locomotive further away from the origin of the signal, but might overload a locomotive computer system close to the origin of the signal with a 20 dBm signal.

Thus, one solution for overcoming signal degradation is to increase the strength of the transmit signal, but attenuate the signal on the receive end so as to not overload computer systems receiving the signal. Such a solution is described in U.S. Patent Publication No. 2012/0163201 (the '201 publication) filed by Williams et al. and published on Jun. 28, 2012. The '201 publication describes a cable modem auto-attenuation system capable of taking a high-power signal from the cable plant's service line, dropping the power value down to a usable level and transmitting the signal to a cable modem. Although the system of the '201 publication may minimally solve the problem of overcoming signal degradation over cable, the system would not be adequate for a trainline communications systems because it is not adapted to interface with trainline communication hardware and does not provide the granularity of attenuation control needed for trainline communication systems.

The disclosed system is directed to overcoming one or more of the problems set forth above.

SUMMARY

In one aspect, the present disclosure is directed to a receive attenuation system for a trainline communication system utilizing intra-consist electrical cable. The system has an analog front end amplifier, a trainline communication processor, an adjustable attenuator, and a gain controller. The trainline communication processor is configured to generate a receive gain control signal configured to control receive gain of the analog front end amplifier. The adjustable attenuator is capable of being coupled to the intra-consist electrical cable and configured to variably attenuate signals received from the intra-consist electrical cable before transmitting the signals to the analog front end amplifier. The gain controller is coupled to the adjustable attenuator and configured to detect the receive gain control signal generated by the trainline communication processor, determine a supplemental attenuation control value based on the detected receive gain control signal, and control the adjustable attenuator according to the supplemental attenuation control signal.

In another aspect, the present disclosure is directed to a method of adjusting receive attenuation in a trainline communication system including detecting a receive gain control signal generated by a trainline communication processor, wherein the receive gain control signal is configured to control receive gain of an analog front end amplifier. The method further includes determining a supplemental attenuation control value based on the detected receive gain control signal,

and controlling an adjustable attenuator according to the supplemental attenuation control signal. The adjustable attenuator is coupled to an intra-consist electrical cable and configured to variably attenuate signals received from the intra-consist electrical cable before transmitting the signals to the analog front end amplifier.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a pictorial illustration of an exemplary disclosed consist;

FIG. **2** is a diagrammatic illustration of an exemplary disclosed communication system that may be used in conjunction with the consist of FIG. **1**;

FIG. **3** is a diagrammatic illustration of an exemplary system for receive attenuation for use with the communication system of FIG. **2**; and

FIG. **4** is a flow chart illustrating an exemplary disclosed method for setting receive attenuation that can be performed by one or more components of FIG. **3**.

DETAILED DESCRIPTION

FIG. **1** illustrates an exemplary train consist **10** having one or more locomotives **12**. In the disclosed embodiment, consist **10** has three different locomotives **12**, including a lead locomotive **12***a* and two trailing locomotives **12***b*, **12***c*. It is contemplated, however, that consist **10** can include any number of locomotives **12** and other cars (e.g. tender cars), and that locomotives **12** can be located in any arrangement and in any orientation (e.g., forward-facing or rear-facing). Consist **10** can be located at the front of a train of other rail vehicles (not shown), within the train of rail vehicles, or at the end of the train of rail vehicles. It is also contemplated that more than one consist **10** can be included within a single train of rail vehicles, if desired, and/or that consist **10** can travel at times without a train of other rail vehicles.

Each locomotive **12** can be connected to an adjacent locomotive **12** in several different ways. For example, locomotives **12** can be connected to each other via a mechanical coupling **16**, one or more fluid couplings **18**, and one or more electrical couplings **20**. Mechanical coupling **16** can be configured to transmit tractive and braking forces between locomotives **12**. Fluid couplings **18** may be configured to transmit fluids (e.g., fuel, coolant, lubrication, pressurized air, etc.) between locomotives **12**. Electrical couplings **20** can be configured to transmit power and/or data (e.g., data in the form of electrical signals) between locomotives **12**. In one example, electrical couplings **20** include an intra-consist electrical cable, such as a MU cable, configured to transmit conventional command signals and/or electrical power. In another example, electrical couplings **20** include a dedicated data link configured to transmit packets of data (e.g., Ethernet data). In yet another example, the data packets can be transmitted via the intra-consist electrical cable. It is also contemplated that some data can be transmitted between locomotives **12** via a combination of the intra-consist electrical cable, the dedicated data link, and/or other means (e.g., wirelessly), if desired.

Each locomotive **12** can include a car body **22** supported at opposing ends by a plurality of trucks **24** (e.g., two trucks **24**). Each truck **24** can be configured to engage a track (not shown) via a plurality of wheels, and to support a frame **26** of car body **22**. Any number of engines **28** can be mounted to frame **26** within car body **22** and drivingly connected to a generator **30** to produce electricity that propels the wheels of each truck **24**. Engines **28** can be internal combustion engines configured to combust a mixture of air and fuel. The fuel can include a liquid fuel (e.g., diesel) provided to engines **28** from a tank **32** located onboard each locomotive **12** or via fluid couplings **18**, and/or a blended mixture of the liquid and gaseous fuels.

As shown in FIG. **2**, consist **10** can be equipped with a communication system **44** that facilitates coordinated control of locomotives **12**. Communication system **44** can include, among other things, an access point **46** for each locomotive **12**. Each access point **46** can be connected to one or more wired and/or wireless networks, and used to communicate command signals and/or data between controllers **48** of each rail vehicle and various other network components **50** (e.g., sensor, valves, pumps, heat exchangers, accumulators, regulators, actuators, GPS components, etc.) that are used to control locomotives **12**. Access points **46** can be connected to each other via electrical couplings **20** (e.g., via the intra-consist electrical cable, via the dedicated data link, and/or wirelessly). Access points **46** can be connected to a local area network hub ("LAN hub") **47** that facilitates communication between the controllers **48**, the network components **50**, and access points **46**.

Each access point **46** can include an inter-consist router ("IC router") **52**, an Ethernet bridge **54**, and an MU modem **56**, as well as conventional computing components known in the art (not shown) such as a processor, input/output (I/O) ports, a storage, a memory. The I/O ports may facilitate communication between the associated access point **46** and the LAN hub **47**. In some embodiments, the I/O ports may facilitate communication between the associated access point **46** and one or more of network components **50**.

Likewise, IC router **52** can facilitate communication between different access points **46** of locomotives **12** that are connected to each other via electrical couplings **20**. In some embodiments, IC router **52** can provide a proxy IP address corresponding to controllers **48** and network components **50** of remote locomotives. For example, IC router **52** can provide a proxy IP address for one of network components **50** of locomotive **12***b* so controller **48** of locomotive **12***a* can communicate with it. The IC router **52** can include, or be connected to, an Ethernet bridge **54** that can be configured to translate network data to an electrical signal capable of being sent through intra-consist electrical cable **58**. Ethernet bridge **54** can include or be connected to MU modem **56**. MU modem **56** can be configured to modulate a carrier signal sent over intra-consist electrical cable **58** with the electrical signal received from Ethernet bridge **54** to transmit network data between access points **46**. MU modem **56** can also be configured to demodulate signals received from access points **46** and send the demodulated signals to Ethernet bridge **54** for conversion to network data destined to controller **48** or network components **50**. In some embodiments, MU modem **56** sends network data orthogonal to data traditionally transmitted over intra-consist electrical cable **58** (e.g., control data). Although FIG. **2** illustrates IC router **52**, Ethernet bridge **54**, and MU modem **56** as separate components, in some embodiments, one component can perform the functionality of two components. For example, Ethernet bridge **54** may perform the operations described above with respect to IC router **52**, or Ethernet bridge **54** can include, or perform the operations of, MU modem **56**.

In some embodiments, access point **46**, IC router **52**, Ethernet bridge **54**, and/or MU modem **56** can include a processor, storage, and/or memory (not shown). The processor can include one or more processing devices, such as microprocessors and/or embedded controllers. The storage can include volatile or non-volatile, magnetic, semiconductor, tape, optical, removable, non-removable, or other type of computer-readable medium or computer-readable storage device. The storage can be configured to store programs and/or other information that can be used to implement one or more of the processes discussed below. The memory can include one or more storage devices configured to store information.

Each controller **48** can be configured to control operational aspects of its related rail vehicle. For example, controller **48** of lead locomotive **12***a* can be configured to control operational aspects of its corresponding engine **28**, generator **30**, traction motors, operator displays, and other associated components. Likewise, the controllers **48** of trail locomotives **12***b* and **12***c* can be configured to control operational aspects of their corresponding engines **28**, generators **30**, traction motors, operator displays, and other associated components. In some embodiments, controller **48** of lead locomotive can be further configured to control operational aspects of trail locomotives **12***b* and **12***c*, if desired. For example, controller **48** of lead locomotive **12***a* can send commands through its access point **46** to the access points of trail locomotives **12***b* and **12***c*.

Each controller **48** can embody a single microprocessor or multiple microprocessors that include a means for controlling an operation of the associated rail vehicle based on information obtained from any number of network components **50** and/or communications received via access points **46**. Numerous commercially available microprocessors can be configured to perform the functions of controller **48**. Controller **48** can include a memory, a secondary storage device, a processor, and any other components for running an application. Various other circuits may be associated with controller **48** such as power supply circuitry, signal conditioning circuitry, solenoid driver circuitry, and other types of circuitry.

The information obtained by a particular controller **48** via access points **46** and/or network components **50** can include performance related data associated with operations of each locomotive **12** ("operational information"). For example, the operational information can include engine related parameters (e.g., speeds, temperatures, pressures, flow rates, etc.), generator related parameters (e.g., speeds, temperatures, voltages, currents, etc.), operator related parameters (e.g., desired speeds, desired fuel settings, locations, destinations, braking, etc.), liquid fuel related parameters (e.g., temperatures, consumption rates, fuel levels, demand, etc.), gaseous fuel related parameters (e.g., temperatures, supply rates, fuel levels, etc.), and other parameters known in the art.

The information obtained by a particular controller **48** via access points **46** and/or network components **50** can also include identification data of the other rail vehicles within the same consist **10**. For example, each controller **48** can include stored in its memory the identification of the particular rail vehicle with which controller **48** is associated. The identification data can include, among other things, a type of rail vehicle (e.g., make, model, and unique identification number), physical attributes of the associated rail vehicle (e.g., size, load limit, volume, power output, power requirements, fuel consumption rate, fuel supply capacity, etc.), and maintenance information (e.g., maintenance history, time until next scheduled maintenance, usage history, etc.). When coupled with other rail vehicles within a particular consist **10**, each controller **48** can be configured to communicate the identification data to the other controllers **48** within the same consist **10**. Each controller **48**, can be configured to selectively affect operation of its own rail vehicle based on the obtained identification data associated with the other rail vehicles of consist **10**.

In some embodiments, controllers **48** can be configured to affect operation of their associated rail vehicles based on the information obtained via access points **46** and/or network components **50** and one or more maps stored in memory. Each of these maps may include a collection of data in the form of tables, graphs, and/or equations. Controllers **48** can be configured to affect operation of their associated locomotives based on the position within a locomotive consist. The position of the locomotive associated with controller **48** can be used with the one or more maps to control the operation of the locomotive. For example, a map of throttle settings can be stored in the memory of controller **48**. The map of throttle settings can include a mapping of consist position to throttle setting. For example, when the locomotive of controller **48** is the lead locomotive (e.g., in first position in the consist) the map may indicate that controller **48** should set the throttle to Notch **4**, and when the locomotive of controller **48** is the third trailing locomotive (e.g., in fourth position in the consist), the map may indicate that controller **48** should set the throttle to Notch **2**.

According to some embodiments, access point **46** can include one or more components for adjusting the attenuation of signals received on intra-consist electrical cable **58**. Attenuation of signals received on intra-consist electrical cable **58** can be important to increase signal strength throughout communication system **44**. For example, controller **48** of lead locomotive **12***a* may transmit a signal over intra-consist electrical cable **58** communicating network data. When the signal reaches access point **46** of locomotive **12***b*, it may be sufficiently strong to communicate the network data, but when the signal reaches access point **46** of locomotive **12***c* (which is further away), the signal may have degraded to an unacceptable level. To ensure that access point **46** of locomotive **12***c* receives sufficient signal, access port **46** of locomotive **12***a* can increase the signal strength of transmissions. In some embodiments, the increase in signal strength is global to all transmissions originating from access port **46** of locomotive **12***a*. As a result, while access point **46** of locomotive **12***c* receives a signal of sufficient strength, access port **46** of locomotive **12***b* receives a signal that is too strong, potentially degrading the signal's integrity and data throughout performance, resulting in reduced bandwidth or, in some cases, complete interruption of communication. By configuring the access points **46** of consist **10** to attenuate receive signals, access point **46** of locomotive **12***a* can send signals via intra-consist electrical cable **58** at a high signal level to accommodate access point **46** of locomotive **12***c*, while not overloading access point **46** of locomotive **12***b* because access point **46** of locomotive **12***b* can attenuate the signal before it reaches components that clip, distort, and degrade signals of high strength.

FIG. **3** is an illustration of an exemplary receive attenuation system **60** for use within communication system **44**. According to some embodiments, receive attenuation system **60** operates to attenuate signals received by access point **46**. Receive attenuation system **60** can include several components such as trainline communication processor **70**, analog front end amplifier **72**, adjustable attenuator **74**, and gain controller **76**. The components of receive attenuation system **60** can be connected by one or more signal paths that are configured to transmit digital or analog signals between the components of receive attenuation system **60**. For example, receive attenuation system **60** can include MU receive signal path **80**, receive gain control signal path **82**, supplemental gain control signal path **84**, attenuated receive signal path **86**, and processor receive signal path **88**. Receive attenuation system **60** can be disposed in, or be part of, access point **46** or one of the components of access point **46**. For example, trainline communication processor **70** can be included in

Ethernet bridge **54**, or it can be a processor that is part of access point **46**. In some embodiments, access point **46** can include a motherboard with one or more expansion slots for accepting daughtercards to enhance the functionality of access point **46**, and the operation of one or more components of receive attenuation system **60** can be embodied on a daughtercard. For example, gain controller **76** and adjustable attenuator **74** can be embodied as daughtercards.

Trainline communication processor **70** can perform operations to enable access point **46** to perform network communications over intra-consist electrical cable **58**. Trainline communication processor **70** can receive incoming signals via processor receive signal path **88**. The incoming signals can include a modulated signal containing network data to be processed by trainline communication processor **70**, or some other component of access point **46**. Conventionally, analog front end amplifier **72** receives incoming signals on MU receive signal path **80** and amplifies or attenuates these signals before they are sent to trainline communication processor **70** on processor receive signal path **88**. Trainline communication processor **70** can control the amplification or attenuation analog front end amplifier **72** provides by sending signals to it via receive gain control signal path **82**. For example, when trainline communication processor **70** receives a signal on processor receive path **88** that is too strong, it can send a signal on receive gain control signal path **82** to request that analog front end amplifier **72** attenuate the signal on processor receive path **88**. By way of further example, when trainline communication processor **70** receives a signal on processor receive path **88** that is too weak, it can send a signal on receive gain control signal path **82** to request that analog front end amplifier **72** amplify the signal on processor receive path **88**.

In some conventional embodiments, while analog front end amplifier **72** can provide some attenuation of the signals received on processor receive path **88**, the attenuation may not be sufficient in some consist communication systems. For example, in consists with a large number of locomotives, signal strength needs to be very high so that signals can traverse intra-consist electrical cables and still be of sufficient strength at either end of the consist. A conventional analog front end amplifier may not provide sufficient attenuation to accommodate the strength of the signal for access points of locomotives that are adjacent or close to each other within the consist. Also, in some conventional embodiments, analog front end amplifier **72** can be embodied within the same component as trainline communication processor **70** (e.g., Ethernet bridge **54**), can be difficult or expensive to replace, or perform functions with legacy hardware that may make analog front end amplifier **72** impractical to replace.

Receive attenuation system **60** overcomes these problems of conventional embodiments by further including adjustable attenuator **74**. As shown in FIG. **3**, adjustable attenuator **74** can be inserted between the analog front end amplifier **72** and intra-consist electrical cable **58**. Adjustable attenuator **74** can be configured to receive incoming signals on MU receive signal path **80**, attenuate the incoming signals, and send the attenuated incoming signals to analog front end amplifier **72**, thereby providing extra attenuation for incoming signals. Adjustable attenuator **74** can include circuitry that is capable of variably attenuating a signal. In some embodiments, adjustable attenuator **74** includes inputs allowing for external control. Adjustable attenuator **74** can be controlled digitally (e.g., by receiving a bit stream of data corresponding to the attenuation level to apply), and/or it can be controlled with an analog signal (e.g., a voltage or current corresponding to the attenuation level to apply). Because receive attenuation system **60** provides multiple levels of attenuation, e.g., one using adjustable attenuator **74** and another using analog front end amplifier **72**, it can provide finer tuned attenuation than that of conventional embodiments.

In some embodiments, adjustable attenuator **74** can be controlled by gain controller **76**. Gain controller **76** can be connected to receive gain control signal path **82** to detect receive gain control signals sent by trainline communication processor **70** to analog front end amplifier **72**. Based on the detected receive gain control signals, gain controller **76** can determine a supplemental attenuation control value. The supplemental attenuation control value can be encoded in a signal that is sent over supplemental attenuation control signal path **84** to adjustable attenuator **74**. Further operations of gain control **76** are described in greater detail below with respect to FIG. **4**.

INDUSTRIAL APPLICABILITY

The disclosed receive attenuation system can be applicable to any consist that includes a plurality of rail cars, such as locomotives. The disclosed receive attenuation system can provide finer granularity of attenuation control than what can be achieved using attenuators currently available in trainline communication analog front end amplifiers. The operation of the receive attenuation system will now be explained.

FIG. **4** is a flowchart illustrating an exemplary disclosed method for setting receive attenuation that can be performed by one of the components illustrated in FIG. **3**. During the operation of consist **10**, gain controller **76** can perform method **400** to adjust receive attenuation using the adjustable attenuator **74**. Although the description that follows describes method **400** as being performed by gain controller **76**, other components of access point **46** can perform one or more of the steps of method **400** in some embodiments.

Gain controller **76** begins method **400** by detecting a receive gain control signal (step **410**). As described above, gain controller **76** can be connected to receive gain control path **82** that trainline communication processor **70** uses to send a receive gain control signal to analog front end amplifier **72**. The receive gain control signal can be, in some embodiments, a digital control signal that specifies to analog front end amplifier **72** the amount of signal attenuation to apply to the data signal that the analog front end amplifier **72** sends to the trainline communication processor **70** via receive signal path **86**. For example, the receive gain control signal can be a 5-bit digital signal from 00000 to 11111. When the receive gain control signal is 00000 the trainline communication processor **70** can command the analog front end amplifier **72** to provide maximum attenuation, and when the receive gain control signal **82** is 11111, the trainline communication processor **70** can command the analog front end amplifier **72** to provide no attenuation. Receive gain control signals between 00000 and 11111 command the analog front end amplifier **72** to provide attenuation somewhere between zero and the maximum attenuation. In some embodiments, the receive gain control signal can be an analog signal that has a variable voltage. When the voltage is low the trainline communication processor **70** commands the analog front end amplifier **72** to provide maximum attenuation, and when the voltage is high the trainline communication processor **70** commands the analog front end amplifier **72** to provide minimum, or zero attenuation. Gain controller **76** can be configured to detect the receive gain control signal, whether digital or analog, to determine whether to control adjustable attenuator **74** to provide supplemental attenuation.

Based on the detected receive gain control signal, gain controller **76** determines a supplemental attenuation control value (step **420**). According to some embodiments, the supplemental attenuation control value is proportionate with the detected receive gain control signal. For example, the receive gain control signal can be a 5-bit digital signal ranging from 00000 to 11111 providing sixteen possible supplemental attenuation control values, including zero. When gain controller **76** detects a receive gain control signal of 11000, it can determine a supplemental attenuation control value that provides 24/31 of the maximum attenuation available with adjustable attenuator **74**. In some embodiments, gain controller **76** can access a data structure or configuration file that specifies the supplemental attenuation control value to use for detected gain control signals. For example, gain controller **76** can access a data structure or configuration file with the data listed below to determine the supplemental attenuation control value for an adjustable attenuator that can be controlled using voltage:

Detected Receive Gain Control Signal	Supplemental Attenuation Control Value
00000	0 V
00001	0 V
00010	0.5 V
00011	0.5 V
00100	0.5 V
00101	0.5 V
00110	0.5 V
00111	0.5 V
01000	1.0 V
01001	1.0 V
01010	1.0 V
01011	1.0 V
01100	1.0 V
01101	1.0 V
01110	1.0 V
01111	1.0 V
10000	1.5 V
10001	1.5 V
10010	1.5 V
10011	1.5 V
10100	1.5 V
10101	1.5 V
10110	1.5 V
10111	1.5 V
11000	2.0 V
11001	2.0 V
11010	2.0 V
11011	2.0 V
11100	2.0 V
11101	2.0 V
11110	3.0 V
11111	3.0 V

As shown in the table above, the use of a configuration file allows gain controller **76** to determine the supplemental attenuation control value according to a step function, if desired. In some embodiments, gain controller **76** can also use a programmatically set function to calculate a supplemental attenuation control value for a detected receive gain control value.

After gain controller **76** determines the supplemental attenuation control value, it can control adjustable attenuator **74** using it (step **430**). As described above, gain controller **76** can send the supplemental control value using supplemental gain control signal path **84**. Once gain controller **76** controls adjustable attenuator **74**, adjustable attenuator **74** attenuates signals received on MU receive signal path **80** before the signals are sent to analog front end amplifier **72**.

Several advantages over the prior art may be associated with the receive attenuation system. The disclosed receive attenuation system can provide finer granularity of attenuation control than what can be achieved using attenuators currently available in trainline communication analog front end amplifiers. In addition, when implemented using daughtercards, the disclosed receive attenuation system can be easily integrate with existing trainline communication systems, including existing Ethernet bridges and/or access points.

It will be apparent to those skilled in the art that various modifications and variations can be made to the receive attenuation system. Other embodiments will be apparent to those skilled in the art from consideration of the specification and practice of the disclosed receive attenuation system. It is intended that the specification and examples be considered as exemplary only, with a true scope being indicated by the following claims and their equivalents.

What is claimed is:

1. A receive attenuation system for a trainline communication system utilizing an intra-consist electrical cable, the system comprising:

an analog front end amplifier;

a trainline communication processor configured to generate a receive gain control signal configured to control receive gain of the analog front end amplifier;

an adjustable attenuator capable of being coupled to the intra-consist electrical cable and configured to variably attenuate signals received from the intra-consist electrical cable before transmitting the signals to the analog front end amplifier; and,

a gain controller coupled to the adjustable attenuator and configured to:

detect the receive gain control signal generated by the trainline communication processor,

determine a supplemental attenuation control value based on the detected receive gain control signal, and

control the adjustable attenuator according to the supplemental attenuation control signal.

2. The receive attenuation system of claim **1**, wherein the analog front end amplifier is configured to further attenuate the signal transmitted from the adjustable attenuator.

3. The receive attenuation system of claim **1**, wherein the adjustable attenuator is a daughtercard.

4. The receive attenuation system of claim **1**, wherein the gain controller is a daughtercard.

5. The receive attenuation system of claim **1**, wherein the receive gain control signal includes a five bit digital signal.

6. The receive attenuation system of claim **1**, wherein the trainline communication processor is part of an Ethernet bridge for the trainline communication system.

7. The receive attenuation system of claim **6**, wherein the analog front end amplifier is part of the Ethernet bridge for the trainline communication system.

8. The receive attenuation system of claim **1**, wherein the supplemental attenuation control value is determined based on data stored in a configuration file.

9. The receive attenuation system of claim **1**, wherein the gain controller controls the adjustable attenuator using a digital command.

10. The receive attenuation system of claim **1**, wherein the gain controller controls the adjustable attenuator using an analog signal.

11. A method of adjusting receive attenuation in a trainline communication system, the method comprising:

detecting a receive gain control signal generated by a trainline communication processor, wherein the receive gain control signal is configured to control receive gain of an analog front end amplifier;

determining a supplemental attenuation control value based on the detected receive gain control signal, and

controlling an adjustable attenuator according to the supplemental attenuation control signal, the adjustable attenuator coupled to an intra-consist electrical cable and configured to variably attenuate signals received from the intra-consist electrical cable before transmitting the signals to the analog front end amplifier.

12. The method of claim **11**, wherein the method is performed by a gain controller including a daughtercard.

13. The method of claim **11**, wherein the receive gain control signal includes a five bit digital signal.

14. The method of claim **11**, wherein controlling the adjustable attenuator includes controlling the adjustable attenuator using a digital command.

15. The method of claim **11**, wherein controlling the adjustable attenuator includes controlling the adjustable attenuator using an analog signal.

16. A locomotive consist comprising:

an intra-consist electrical cable;

a first locomotive having a first access point configured to transmit signals via the intra-consist electrical cable;

a second locomotive having a second access point including:

an Ethernet bridge including a trainline communication processor configured to generate receive gain control signals;

an analog front end amplifier coupled to the Ethernet bridge and configured to receive the gain control signals from the trainline communication processor;

an adjustable attenuator coupled to the intra-consist electrical cable and the analog front end amplifier, the adjustable attenuator configured to variably attenuate the signals received from the first access point via the intra-consist electrical cable before transmitting the received signals to the analog front end amplifier; and

a gain controller coupled to the adjustable attenuator configured to:

detect the receive gain control signals generated by the trainline communication processor,

determine a supplemental attenuation control value based on the detected receive gain control signal, and

control the adjustable attenuator according to the supplemental attenuation control signal.

17. The locomotive consist of claim **16** wherein the gain controller and the adjustable attenuator constitute on one or more daughtercards.

18. The locomotive consist of claim **16** wherein the receive gain control signal includes a five bit digital signal.

19. The locomotive consist of claim **16** wherein the adjustable attenuator is controlled using a digital command.

20. The locomotive consist of claim **16** wherein the adjustable attenuator is controlled using an analog signal.

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