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Audio System

(93)

FIELD OF THE INVENTION

The invention relates to an audio system for transmitting audio signals through a power line.

BACKGROUND

As most households have power sockets that are coupled to a common power line, the sending of data through the power line, known as power line communication (PLC), serves as a convenient way to transmit data from a transmitter to a receiver. This is because the data transmission medium already exists without the further need to install further infrastructure.

There are known PLC transmitter and receiver modules that serve to enable the transmission of audio signals through the power line. Some of these known modules locate the carrier frequency to transmit the audio signal based on the criteria of the best impedance characteristic match of the power line at the instant the modules are operated. However, the same carrier frequency will be used regardless of whether noise arises during the modules operation that causes the carrier frequency to become unsuitable to transmit the audio signal. In terms of the selection of the transmission carrier frequency used, the PLC transmitter and receiver modules remain static after the initial selection of the carrier frequency.

Further, as noise arises during the transmission of the audio signal, the quality of the transmitted audio signal may no longer be maintainable at a desirable level for the initially selected carrier frequency. However, as the known PLC transmitter and receiver modules continue to use the same carrier frequency to transmit the audio signal, the quality of the transmitted audio signal cannot be maintained at the desired level.

There is thus a need to have a device that addresses one or more of the above disadvantages.

SUMMARY OF THE INVENTION

According to a first aspect of the invention, there is provided an audio system for transmitting audio signals through a power line, the audio system comprising a display unit; a transmitter module coupled to the power line; and a primary controller coupled to the transmitter module, where the primary controller interrogates the transmitter module to determine a transmission status of the transmitted audio signals and wherein the display unit displays the transmission status of the transmitted audio signals for view by a user.

- 10 The display unit may display visual indicators representative of a carrier frequency selected to transmit the audio signals, a transmission quality of the carrier frequency selected, or both.

The visual indicators may include a symbol to represent the carrier frequency selected and a bar chart to represent the transmission quality.

The display unit may display an element associated with an audio quality mode of the transmitted audio signals.

- 20 The primary controller may automatically change the carrier frequency used when the transmitted audio signals falls below a threshold audio quality mode.

The audio system may further comprise a user interface for activating the primary controller to instruct the transmitter module to change the carrier frequency based on a user input.

The primary controller may instruct the transmitter module to change to a different carrier frequency selected to transmit the audio signals based on user instruction.

- 30 The primary controller may instruct the transmitter module to scan to find a highest status carrier frequency to transmit the audio signals.

The user interface may comprise one or more entry buttons.

The audio system may further comprise a remote control unit having a second display unit.

5 The second display unit may display visual indicators representative of the carrier frequency selected, a transmission quality of the carrier frequency selected, or both.

The visual indicators may include a symbol to represent the carrier frequency selected and a bar chart to represent the transmission quality.

10 The second display unit may display an element associated with an audio quality mode of the transmitted audio signals.

The audio system may further comprise two or more receiver units coupled to the power line for receiving a first transmitted audio signal and/or a second transmitted
15 audio signal.

In one operation mode, the first and second audio signals may comprise a left and right channel from a same audio source, wherein the two or more receiver units receive the left and right channels for outputting the same audio.

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In another operation mode, the first and second audio signals may comprise audio data from two different audio sources, wherein one of the two or more receiver units receives the first audio signal while the other of the two or more receiver units receives the second audio signal, so that the two or more receiver units output different audio.

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The audio signals may comprise audio data from one or more of a group consisting of a disc player capable of reading discs in CD, DVD or MP3 format and a radio receiver.

30 The audio system may further comprise an audio source interface, wherein the audio source interface comprises one or more of a group consisting of a memory card reader, a portable source medium reader, an adaptor for connecting a portable hard disk and a connector for connecting to an external audio device.

BRIEF DESCRIPTION OF THE DRAWINGS

This present invention is now be described by way of non-limiting examples, with reference to the accompanying drawings, in which:

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Figure 1 shows a system built in accordance with one embodiment of the invention.

Figure 2 shows an electrical schematic of the system of Figure 1.

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Figure 3 shows a component layout of the Mitsubishi MLD011TM PLC transmitter.

Figure 4 shows the 8 carrier frequencies available for use by the PLC transmitter module when it is sending an RF signal from a high frequency of around 2MHz to around 20MHz.

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Figure 5 shows a component layout of the Mitsubishi MLD011RM PLC receiver module.

DESCRIPTION OF EMBODIMENTS OF THE INVENTION

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Figure 1 shows a system 100 built in accordance with one embodiment of the invention.

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The system 100 comprises a multi-function stereo set 102, a first speaker unit 104 and a second speaker unit 106 and a remote control unit 142. The multi-function stereo set 102 is in electrical communication with the one or more speaker units 104 and 106 through a common power line 108.

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The multi-function stereo set 102 has a primary controller 144, a Power Line Communication (PLC) transmitter module 114 and a power supply 116. The PLC transmitter module 114 has a transmitter processor 146. The primary controller 144 is coupled 112 to the PLC transmitter module 114 and communicates with the transmitter processor 146 in a duplex manner. The power supply 116 and the PLC transmitter module 114 are both coupled to the power line 108 through a switch 118. A light emitting diode (LED) 117 indicates whether the switch 118 has been closed. The

multi-function stereo set 102 also houses one or more of the components: a disc player capable of reading discs in CD, DVD or MP3 format and a radio receiver. These one or more components are indicated as reference numeral 110. In addition, the multi-function stereo set 102 has an audio source interface 156, the audio source interface 156 comprising one or more of a group consisting of a memory card reader, a portable source medium reader, an adaptor for connecting a portable hard disk and a connector for connecting to an external audio device. Also present on the multi-function stereo set 102 is an infra-red detector 182 for receiving signals sent by the remote control unit 142.

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The multi-function stereo set 102 also has a user interface 158 for activating the primary controller 144 based on a user input. The user interface 158 has one or more entry buttons 160 and a display unit 162. The one or more entry buttons 160 allow a user to activate the primary controller 144 and thereby operate the system 100. The display unit 162 displays visual indicators of the operation status of the system 100. These visual indicators include a symbol 168 (such as a numeral) representative of a carrier frequency selected to transmit audio signals, a bar chart 166 representative of the transmission quality of the carrier frequency selected and an element 164 associated with an audio quality mode of the transmitted audio signals. Thus, the visual indicators enable the user to know the signal strength of the transmitted audio signals and their associated audio quality, in contrast with other conventional display units.

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The first speaker unit 104 has a power supply 120, a PLC receiver module 122, a switch 124, a processor 184, a remote control sensor 186 and a pair of left (L) and right (R) speakers 126. The PLC receiver module 122 has a first receiver processor 148. The power supply 120 and the PLC receiver module 122 are both coupled to the power line 108 through a switch 128, while the speakers 126 are coupled to the PLC receiver module 122 through the switch 124. An LED 127 indicates whether the switch 128 has been closed. The first speaker unit 104 also has a user interface 170 which functions in largely the same manner as the user interface 158 of the multi-function stereo set 102.

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The second speaker unit 106 has a power supply 130, a PLC receiver module 132, a mixer module 134, a processor 190, a remote control sensor 192 and a speaker 136. The PLC receiver module 132 has a second receiver processor 150. The power supply 130 and the PLC receiver module 132 are both coupled to the power line 108 through a switch 138, while the speaker 136 is coupled to the PLC receiver module 132 through the mixer module 134. An LED 137 indicates whether the switch 138 has been closed. The second speaker unit 106 also has a user interface 172 which functions in largely the same manner as the user interface 158 of the multi-function stereo set 102.

A user can operate the system 100 directly from the multi-function stereo set 102, the first speaker unit 104 or the second speaker unit 106 through their respective user interfaces 158, 170 or 172. Alternatively, the user can also use the remote control unit 142 to operate the system 100 when the user is standing a distance away from the system 100. The remote control unit 142 has a second display unit 176 and one or more entry buttons 174. The one or more entry buttons 174 allow a user to activate the primary controller 144 and thereby operate the system 100. The second display unit 176 provides visual indicators of the operation status of the system 100. These visual indicators include a symbol 178 (such as a numeral) representative of a carrier frequency selected to transmit audio signals, a bar chart 182 representative of the transmission quality of the carrier frequency selected and an element 180 associated with an audio quality mode of the transmitted audio signals.

The remote control unit 142 may also be directed at either the first speaker unit 104 or the second speaker unit 106 to control the system 100. The signal from the remote control unit 142 can be received at the remote control sensor 186 at the first speaker unit 104 and at the remote control sensor 192 at the second speaker unit 106. The respective processors 184 and 190 process the received signal from the remote control unit 142 and send corresponding control signals back to the multi-function stereo set 102.

The system 100 is used to transmit audio from the multi-function stereo set 102 as audio signals embedded in a radio frequency (RF) signal to the speaker units 104 and 106 through the power line 108. The system 100 is capable of transmitting audio

signal data from two different audio sources simultaneously. The audio sources comprise any one or more of the components indicated as reference numeral 110, i.e. a disc player capable of reading discs in CD, DVD or MP3 format and a radio receiver or any other external audio device connected to the multi-function stereo set 102
5 through the audio source interface 156.

The system 100 has two operation modes, namely a "stereo operation mode" and a "dual operation mode".

10 In the stereo operation mode, the multi-function stereo set 102 transmits first and second audio signals comprising a left and right channel from a same audio source, wherein the first speaker 104 and the second speaker 106 receive the left and right channels for outputting the same audio.

15 On the other hand, in the dual operation mode, the multi-function stereo set 102 transmits first and second audio signals comprising audio from two different audio sources, as two mono signals, to both the first speaker unit 104 and the second speaker unit 106, wherein the first speaker unit 104 receives the first audio signal while the second speaker unit 106 receives the second audio signal so that the two
20 speaker units 104 and 106 output different audio.

At the beginning of the system 100 operation, the primary controller 144 will select an audio source from any one of the components 110 or from an external audio source connected to the audio source interface 156.

25 The primary controller 144 then sends a signal carrying the audio source data to the PLC transmitter module 122 through the coupling 112. At the PLC transmitter module 114, the audio source data signal is processed for transmission as a radio frequency (RF) signal 140 in the high frequency (HF) band from about 2 MHz to about 20MHz.
30 The RF signal 140 is then transmitted through the power line 108 for receiving by the speaker units 104 and 106. Similarly, control signals between the multi-function stereo set 102 and the speaker units 104 and 106 are sent over the power line 108.

Before the PLC transmitter 114 transmits the RF signal 114, the PLC transmitter module 114 automatically selects the optimal carrier frequency that matches the impedance characteristic changes of the power line 108 for transmission of the RF signal 140. The primary controller 144 coupled to the PLC transmitter 114 interrogates the PLC transmitter 114 to determine the transmission status of the RF signal 140. The primary controller 144 then sends a control signal to the display unit 162 and the second display unit 176 to display the transmission status for view by a user. Additionally, corresponding control signals may be sent to display screens (not shown) in the user interfaces 170 and 172 at the speaker units 104 and 106 respectively. In this manner, the selected optimal carrier frequency is displayed in the display unit 162 and the second display unit 176 as the symbols 168 and 178. The transmission quality of the selected carrier frequency is shown as the bar charts 166 and 182.

However, data transmission errors may arise due to fluctuations in the power line 108 that render the initially chosen carrier frequency unsuitable for continuous transmission of the RF signal 140. The user interfaces 158, 170 and 172 or the remote control unit 142 can then be operated to activate the primary controller 144 to instruct the PLC transmitter module 114 to select another carrier frequency to transmit the RF signal 140. Without this intervention, the PLC transmitter module 114 does not automatically select a new carrier frequency to transmit the RF signal 140, i.e. the same initially chosen carrier frequency will be used throughout the system 100 operation for transmitting the RF signal 140. Another advantage the user interfaces 158, 170 and 172 and the remote control unit 142 provide is to allow a user to scroll through the carrier frequencies that are available even if the initially chosen carrier frequency can still transmit the RF signal 140, for instance when the initially chosen carrier frequency is unable to support transmission of a high audio mode.

The quality of the audio signal transmitted by the RF signal 140 is divided into 15 different categories, known as audio quality modes, where each mode has a corresponding sampling rate and bit length. The 15 different modes are described later with reference to table 3. After the PLC transmitter module 114 has chosen the optimal carrier frequency to transmit the RF signal 140, the PLC transmitter module 114 will transmit the audio signal using the highest possible audio quality mode available to the chosen carrier frequency.

The primary controller 144 coupled to the PLC transmitter module 114 sends a control signal to the display unit 162 and the second display unit 176 to display the audio quality mode selected by the PLC transmitter module 114. Additionally, corresponding control signals may be sent to the screens (not shown) in the user interfaces 170 and 172 at the speaker units 104 and 106 respectively. In this manner, the selected audio quality mode is displayed in the display unit 162 and the second display unit 176 as the elements 164 and 180. However, when data transmission errors occur due to fluctuations in the power line 108, a high audio quality mode may no longer be achievable. The PLC transmitter module 114 will then transmit the RF signal using a lower audio quality mode. The primary controller 144 then sends another control signal to refresh the elements 164 and 180 to display the selected lower quality mode. Additionally, corresponding control signals may be sent to the screens (not shown) in the user interfaces 170 and 172 respectively. The primary controller 144 can then be operated to instruct the PLC transmitter module 114 to select another carrier frequency capable of transmitting the RF signal 140 in the high audio quality mode. Alternatively, the PLC transmitter module 114 can be pre-programmed by the primary controller 144 to only transmit audio signals on or above a predefined audio quality mode. In this manner, the PLC transmitter module 114 will select another suitable carrier frequency to transmit the RF signal 140 if at a particular instant the current selected carrier frequency is unable to transmit the RF signal 140 at the predefined audio quality mode.

The primary controller 144 may also provide an auto-tuning function whereby the PLC transmitter module 114 is instructed to perform a check of the best carrier frequency used to transmit the RF signal 140 and accordingly select the best carrier frequency upon user activation. Advantageously, this can avoid having to power up and power down the PLC transmitter module 114 and the PLC receiver modules 122 and 132 each time a different carrier frequency is desired by the user.

By itself, the PLC transmitter module 114 will transmit the RF signal 140 without checking whether the transmitted RF signal 140 is above any threshold audio quality mode. Further, as earlier mentioned, the PLC transmitter module 114 continues to use the same initially chosen carrier frequency throughout the system 100 operation for

transmitting the RF signal 140. Thus, the system 100 provides a mechanism for allowing selective audio quality mode transmission to maintain the transmitted audio at or above a certain level.

- 5 Turning to the receiver end, the first speaker unit 104 and the second speaker unit 106 will receive the RF signal 140 through the power line 108.

At the first speaker unit 104 and the second speaker unit 106, the respective PLC receiver modules 122 and 132 process the RF signal 140 and extract the audio signal data present in the RF signal 140.

The stereo operation mode is first considered, where the extracted data is first and second audio signals comprising a left channel and a right channel from a same audio source, i.e. the extracted data is a stereo signal. At the first speaker unit 104, the left channel will be sent to the left speaker 126 while the right channel will be sent to the right speaker 126 so that sound is heard from the speakers 126. At the second speaker unit 106, both the left and right channels will be sent to the speaker 136 so that audio sound is heard from the speaker 136. In this manner, the first and the second speaker units 104 and 106 emit the same audio.

20 On the other hand, in the dual operation mode, the extracted audio data is first and second audio signals comprising audio data from two different audio sources, the first and second audio signals being two mono signals. At the first speaker unit 104, the first receiver processor 148 selects the first audio signal for transmission to the speakers 126 and discards the second audio signal. The first audio signal is then sent to both the left speaker 126 and the right speaker 126 so that sound is heard from the speakers 126. At the second speaker unit 106, the second receiver processor 150 selects the second audio signal for transmission to the speaker 136 and discards the first audio signal. The second audio signal is then sent to the speaker 136 so that sound is heard from the speaker 136. In this manner, the first and the second speaker units emit different audio.

Thus, consider the scenario where the system 100 is used in an apartment with one or more rooms and each of the speaker units 106 and 108 is placed in a separate room.

When the system 100 is operating in the stereo operation mode, both rooms will have the same music playing. On the other hand, when the system 100 is operating in the dual operation mode, the two rooms will have different music playing as determined by the settings on the first speaker unit 104 and the second speaker unit 106.

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It will be appreciated that the system 100 can be adapted for other multi-channel configurations. For example, in a six channel configuration one 5+1 surround sound audio signal may be transmitted to all speakers in one operation mode, while three different stereo signals or six different mono signals could be transmitted in other operation modes, using six channel transmitter and receiver configurations.

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Figure 2 shows an electrical schematic 200 of the system 100 of Figure 1. The same reference numerals have been used in indicate the same components in Figures 2 and 1. Figure 2 only illustrates the connection between the multi-function stereo set 102 and the first speaker unit 104.

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In the example embodiment, the PLC transmitter module 114 used is Mitsubishi model number MLD011TM while the PLC receiver module 122 used is Mitsubishi model number MLD011RM. It will be appreciated that other PLC transmitter and receiver modules may be used.

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Figure 2 illustrates that the multi-function stereo set 102 has a surge absorber 218 and a blocking filter 220. The surge absorber 218 and the blocking filter 220 are electrically coupled to the PLC transmitter module 114. Further, the surge absorber 218 is electrically coupled to the common power line 108 and the blocking filter 220.

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The PLC transmitter module 114 has an Analog to Digital Converter (ADC) 204 in electrical communication with an oscillator (OSC) 206, an audio input 236 and the transmitter processor 146. The transmitter processor 146 is in electrical communication with a Read Only Memory (ROM) module 210 and an Analog Front End (AFE) IC chip 212. The AFE IC 212 is in electrical communication with an X'tal module 214 and an alternating current (AC) power line coupling 216. The AC power line coupling 216 is in electrical communication with the blocking filter 220 and the

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surge absorber 218. The surge absorber 218 is then electrically connected to the common power line 108.

Figure 2 also illustrates that the multi-function stereo set 102 has an analog signal generator 228 and a status indicator board 229. The primary controller 144 and the status indicator board 229 are in electrical communication with the transmitter processor 146, while the analog signal generator 228 is in electrical communication with the ADC 204.

The status indicator board 229 has a Light Emitting Diode (LED) 230 and switch 232.

Figure 2 illustrates that the first speaker unit 104 has a surge absorber 246 and a blocking filter 248. The surge absorber 246 and the blocking filter 248 are electrically connected to the PLC receiver module 122. Further, the surge absorber 246 is electrically connected to the common power line 108 and the blocking filter 248.

The PLC receiver module 122 has a Digital to Analog Converter (DAC) 252 in electrical communication with an oscillator (OSC) 254, an audio output 276 and the first receiver processor 148. The first receiver processor 148 is in electrical communication with a ROM module 258 and an AFE IC chip 260. The AFE IC 260 is in electrical communication with an X'tal module 262 and an AC power line coupling 264. The AC power line coupling 264 is in electrical communication with the blocking filter 248 and the surge absorber 246. The surge absorber 246 is then electrically connected to the common power line 108.

The surge absorbers 218 and 246 respectively serve to protect the multi-function stereo set 102 and the first speaker unit 104 from power fluctuations and sudden power surges from the power line 108. The blocking filters 220 and 248 prevent the RF signals 140 from being directed towards the power supplies 116 and 120 respectively. The power supplies 116 and 120 convert the alternating current from the power line 108 into direct currents. In addition, the power supplies 116 and 120 also act to step down the high voltage (of around 85V to around 276V) of the power line 108 into the low voltages (of around 3.3V to around 9.0V) that are used to power all

the electrical components present in the multi-function stereo set 102 and the first speaker unit 104.

Figure 3 shows a component layout of the Mitsubishi MLD011TM PLC transmitter module 114 used in the example embodiment. The same reference numerals have been used in indicate the same components in Figures 3 and 2.

The PLC transmitter module 114 interfaces with the primary controller 144 and/or other peripheral devices, such as an external CD player or a power line through the appropriate connectors 322, 324 and 326. The connectors 322, 324 and 326 are devices that comprise 2 electrical contact pins, 6 electrical contact pins and 12 electrical contact pins. Thus the pins allow peripheral devices access to the various functions the PLC transmitter module 114 can perform by sending an appropriate signal through the appropriate pin. The pin assignment for the connectors 322, 324 and 326 are summarised in table 1 below. The third column of table 1 is used to indicate whether the pin in question receives a signal (referred to as "in"), transmits a signal (referred to as "out"), or receives or transmits a signal (referred to as "in/out") depending on the instantaneous circumstance.

Table 1: Pin Assignment For Connectors 322, 324 and 326Connector	Pin No.	In/Out	Terminal Function	Signal Characteristic
322 (B2P3-VH/JST)	1	In/Out	AC100V (L) RF Signal	
	2	In/Out	AC100V (N) RF Signal	
324 (B6B-PH-K-S/JST)	1	In	Analog Audio Right Channel Signal	1 Vrms max
	2	-	Ground	Analog audio
	3	In	Analog Audio Left Channel Signal	1 Vrms max
	4	-	Ground	
	5	In	Vcc2	DC+3.3V
	6	In	Vcc1	DC+5.0V
326 (B12B-PH-KS/JST)	1	-	Ground	
	2	In	Optimal carrier assignment function	Active high Relocate with L-> H transition
	3	-	NC	
	4	-	NC	

	5	-	NC	
	6	Out	Display connection output status	Operation: Active High
	7	In	Mute control input	Active Low
	8	-	NC	
	9	In	Registration of group identification number	Active Low
	10	In	UART (RX)	Serial interface Mark: +3.3V / Space: 0V
	11	Out	UART (TX)	
	12	-	GND	

Turning to the connector 326, the connector 326 provides an interface for peripheral devices to access the transmitter processor 146 of the PLC transmitter module 114.

- 5 Pins 2 and 7 of the connector 326 are input pin ports that accept input voltage levels of around 3.3V and have an impedance of around 10kΩ. Input signals that have a voltage level of 0.8V or less will be treated as a digital low level logic "0", while input signals that have a voltage level of 2.0V or more will be treated as a digital high level logic "1".

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- The carrier frequency that the PLC transmitter module 114 uses to transmit audio signals to one or more receiver modules is controlled by sending an appropriate signal through pin 2 of the connector 326. When a digital high level logic "1" signal is being transmitted via pin 2, the PLC IC 302 will react accordingly to use the appropriate carrier frequency selected. Otherwise, when a digital low level logic "0" signal is being transmitted via pin 2, the PLC transmitter module 114 will automatically search and use a carrier frequency that best matches the impedance characteristics of power lines for transmitting audio signals. Thus, an external mechanism for controlling the carrier frequency used is provided.

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- Pin 6 of the connector 326 is an output pin port that outputs voltage levels of around 3.3V and has an impedance of around 10kΩ. Output signals that have a voltage level of 0.4V or less will be treated as a digital low level logic "0", while output signals that have a voltage level of 2.4V or more will be treated as a digital high level logic "1". The digital low level and digital high level signals have a current of 2mA or less.

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The link condition status of the PLC transmitter module 114 is determined by tapping the output signal at pin 6 of the connector 326. The operation of pin 6 is summarised below in table 2.

5 Table 2: Operation Of Pin 6 Of Connector 326

Pin 6 output	Transmitter Module Status	Type of operation
High	Audio signals are received by one or more receiver modules.	Normal operation
High/Low	Link is being established with one or more receiver modules	Optimal carrier arrangement registration
Low	No receiver modules linked.	No operation

When pin 6 of the connector 326 outputs a digital high level logic signal, it indicates that the PLC transmitter module 114 is operating normally, i.e. transmitted audio
 10 signals are being received by one or more receiver modules. When pin 6 of the connector 326 outputs a digital low level logic signal, it indicates that the PLC transmitter module 114 is not transmitting audio signals as there are no receiver modules connected to a power line. When the PLC transmitter module 114 is establishing a data communication link with one or more receiver modules using
 15 optimal carrier arrangement, pin 6 will output a repeating sequence of a digital high level logic signal for 0.6s followed by a digital low level logic signal for 0.4s.

Thus by tapping the output of pin 6, a means is provided to determine the transmission status of the PLC transmitter module 114. The primary controller 144 (Figure 1)
 20 interrogates the transmitter processor 146 through pin 6 to ascertain the transmission status of the PLC transmitter module 114. The transmission status is shown in the display unit 162 and the second display unit 176 as the bar charts 166 and 176. The transmission status is also shown in the display screens (not shown) of the user interfaces 170 and 172.

25 The muting of audio signals being transmitted by the PLC transmitter module 114 is achieved by sending an appropriate signal through pin 7 of the connector 326. Pin 7 is active when there is a digital low level logic "0" signal present. The primary controller 144 (Figure 1) will invoke the mute function by sending an appropriate signal through
 30 pin 7 of the connector 326 to cause the first speaker unit 104 (Figure 1) and the

second speaker unit 106 (Figure 1) to stop emitting sound when the carrier frequency used to transmit audio signals is changed. The first speaker unit 104 (Figure 1) and the second speaker unit 106 (Figure 1) will stop emitting sound for the duration that the PLC transmitter module 114 takes to select another carrier frequency.

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At this point, how the system 100 (Figure 1) achieves the selection of a different transmission carrier frequency, from the initially selected optimal carrier frequency, and the selection of a desired audio quality mode is explained with reference to the working of pins 2, 6 and 7 of the connector 326.

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There are a total of 19 carrier frequencies for transmission of audio signals through a power line. The PLC transmitter module 114 uses any one of 8 of these 19 carrier frequencies that are in the high frequency band of about 2 MHz to about 20MHz to transmit RF signals.

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Figure 4 shows the 8 carrier frequencies (402a, 402b, ..., 402g) available for use by the PLC transmitter module 114 (Figure 1) when it is sending the RF signal from a high frequency of around 2MHz to around 20MHz. After the PLC transmitter module 114 (Figure 1) automatically selects the best initial carrier frequency, for example carrier frequency 402a, the PLC transmitter module 114 (Figure 1) continues using the carrier frequency 402a regardless of whether noise arising during the transmission of RF signals causes the selected carrier frequency 402a to become unsuitable for continuous transmission.

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25 The transmission status of the selected carrier frequency 402a is output through pin 6 of the connector 326 (Figure 3) and reflected on the display unit of the remote control unit 142 (Figure 1). The remote control unit 142 (Figure 1) can then be operated to command the primary controller 144 (Figure 1) to instruct the PLC transmitter module 114 (Figure 1) to select another carrier frequency (402b, 402c, ... 402g) to use for the
30 transmission of the RF signals, especially when the selected carrier frequency 402a has become unsuitable for continuous transmission. When the remote control 142 (Figure 1) is so operated, pin 2 of the connector 326 (Figure 3) will receive a digital high level logic "1" signal from the primary controller 144 (Figure 1). Alternatively, for the PLC transmitter module 114 to select a new carrier frequency, a Universal

Asynchronous Receiver/Transmitter (UART) command ":LOC[CR]" can be input into the PLC transmitter module 114 (Figure 1).

When a new carrier frequency is selected, the mute function will be invoked through the sending of an appropriate signal through pin 7 of the connector 326 (Figure 3).

The audio quality of the RF signal 140 (Figure 1) is categorised into 15 different modes, with each mode having a corresponding sampling rate and bit length. The characteristics of the 15 different modes are summarised in table 3.

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Table 3: Characteristics Of Audio modes

Mode	Sampling rate	Bit length	Mode down threshold PER	Mode up threshold PER
15	44.1k	16bit	1-247/255	1-247/255
14	44.1k	16bit	1-247/255	1-247/255
13	44.1k	16bit	1-255/255	1-255/255
12	44.1k	10bit	1-247/255	1-247/255
11	44.1k	12bit	1-255/255	1-255/255
10	44.1k	8bit	1-247/255	1-247/255
9	44.1k	10bit	1-255/255	1-255/255
8	44.1k	8bit	1-254/255	1-254/255
7	32k	9bit	1-204/255	1-204/255
6	32k	12bit	1-247/255	1-247/255
5	32k	9bit	1-247/255	1-247/255
4	22.5k	10bit	1-235/255	1-235/255
3	22.5k	9bit	1-255/255	1-255/255
2	22.5k	8bit	1-204/255	1-204/255
1	22.5k	8bit	1-204/255	1-204/255

Returning to Figure 1, after the PLC transmitter module 114 has selected the optimal carrier frequency to transmit the RF signal 140, the PLC transmitter module 114 will transmit the audio signal using the highest possible audio quality mode available to the selected carrier frequency.

The primary controller 144 coupled to the PLC transmitter module 114 sends a control signal to the display unit 162 and the second display unit 176 to display the audio quality mode selected by the PLC transmitter module 114. Additionally, corresponding control signals may be sent to the screens (not shown) in the user interfaces 170 and 172 at the speaker units 104 and 106 respectively. In this manner, the selected audio

quality mode is displayed in the display unit 162 and the second display unit 176 as the elements 164 and 180. However, when data transmission errors occur due to fluctuations in the power line 108, a high audio quality mode, for example audio mode 14, may no longer be achievable. The PLC transmitter module 114 will then transmit
5 the RF signal 140 using a lower audio quality mode, for example audio mode 7. . The primary controller 144 then sends another control signal to refresh the elements 164 and 180 to display the selected lower quality mode. Additionally, corresponding control signals may be sent to the screens (not shown) in the user interfaces 170 and 172 respectively. The primary controller 144 can then be operated to instruct the PLC
10 transmitter module 114 to select another carrier frequency capable of transmitting the RF signal 140 in the high audio quality mode. Alternatively, the PLC transmitter module 114 can be pre-programmed by the primary controller 144 to only transmit audio signals on or above a predefined audio quality mode. In this manner, the PLC transmitter module 114 will select another suitable carrier frequency to transmit the RF
15 signal 140 if at a particular instant the current selected carrier frequency is unable to transmit the RF signal 140 at the predefined audio quality mode.

By itself, the PLC transmitter module 114 will transmit the RF signal 140 without checking whether the transmitted RF signal 140 is above a threshold audio quality
20 mode. Further, as earlier mentioned, the PLC transmitter module 114 continues to use the same initially chosen carrier group throughout the system 100 operation for transmitting the RF signal 140. Thus, the system 100 provides a mechanism for allowing selective audio quality mode transmission to maintain the transmitted audio at or above a certain level.

25 Figure 5 shows a component layout of the Mitsubishi MLD011RM PLC receiver module 122/132 used in the example embodiment. The same reference numerals have been used in indicate the same components in Figures 5 and 2.

30 The PLC receiver module 122/132 interfaces with the multi-function stereo set 102 through the power line 108 (Figure 1) through the appropriate connectors 522, 524 and 526. The connectors 522, 524 and 526 are devices that respectively comprise 2 electrical contact pins, 8 electrical contact pins and 12 electrical contact pins. Thus the pins allow peripheral devices access to the various functions the PLC receiver

module 122/132 can perform by sending an appropriate signal through the appropriate pin. The pin assignment for the connectors 522, 524 and 526 are summarised in table 4 below. The third column of table 4 is used to indicate whether the pin in question receives a signal (referred to as "in"), transmits a signal (referred to as "out"), or receives or transmits a signal (referred to as "in/out") depending on the instantaneous circumstance.

Table 4: Pin Assignment For Connectors 522, 524 and 526

Connector	Pin No.	In/Out	Terminal Function	Signal Characteristic
522 (B2P3-VH/JST)	1	In/Out	AC100V RF Signal	
	2	In/Out	AC100V RF Signal	
524 (B8B-PH-SM3/JST)	1	Out	Analog Audio Right Channel Signal	1 Vrms max
	2	-	Ground	
	3	Out	Analog Audio Left Channel Signal	1 Vrms max
	4	-	Ground	Power supply for audio amplifier DC+5.0V -+ 9.0V
	5	In	Vcc3	
	6	-	Ground	Common for +3.3V/+5.0V
	7	In	Vcc2	DC +3.3V
	8	In	Vcc1	DC +5.0V
526 (B12B-PH-SM3/JST)	1	-	Ground	
	2	In	Optimal carrier assignment function	Active high Relocate with L->H transition
	3	-	NC	
	4	-	NC	
	5	-	NC	
	6	Out	Display connection output status	Operation: Active High
	7	Out	Mute control input	Active Low
	8	-	NC	
	9	In	Registration of group identification number	Active Low
	10	In	UART (RX)	Serial interface Mark: +3.3V / Space: 0V
	11	Out	UART (TX)	
	12	-	GND	

Turning to the connector 526, the connector 526 provides an interface for peripheral devices to access the receiver processor 148/150 of the PLC receiver module

122/132. Pin 6 of the connector 526 is an output pin port that outputs voltage levels of around 3.3V and has an impedance of around 10kΩ. Output signals that have a voltage level of 0.4V or less will be treated as a digital low level logic "0", while output signals that have a voltage level of 2.4V or more will be treated as a digital high level logic "1". The digital low level and digital high level signals have a current of 2mA or less.

The link condition status of the PLC receiver module 122/132 is determined by tapping the output signal at pin 6 of the connector 526. The operation of pin 6 is summarised below in table 5.

Table 5: Operation Of Pin 6 Of Connector 526

Pin 6 output	Transmitter Module Status	Type of operation
High	Audio signals are received by one or more transmitter modules.	Normal operation
High/Low	Link is being established with one or more transmitter modules	Optimal carrier arrangement registration
Low	No transmitter modules linked.	No operation

When pin 6 of the connector 526 outputs a digital high level logic signal, it indicates that the PLC receiver module 122/132 is operating normally, i.e. the PLC receiver module 122/132 is receiving audio signals sent by one or more transmitter modules. When pin 6 of the connector 526 outputs a digital low level logic signal, it indicates that the PLC receiver module 122/132 is not receiving audio signals, e.g. because there are no transmitter modules connected to a power line. When the PLC receiver module 122/132 is establishing a data communication link with one or more transmitter modules using optimal carrier arrangement, pin 6 will output a repeating sequence of a digital high level logic signal for 0.6s followed by a digital low level logic signal for 0.4s.

Thus by tapping the output of pin 6, a means is provided for the transmitter module 114 (Figure 3) to determine the receiving status of the PLC receiver module 122/132, and in turn the transmitter module 114 (Figure3) will set the output of pin 6 of connector 326 (Figure 3) accordingly, for interrogation by the primary controller 144 (Figure 1) as described above with reference to Figure 3.

Pin 7 of the connector 526 is an input pin port that accepts input voltage levels of around 3.3V and has an impedance of around 10k Ω . Input signals that have a voltage level of 0.8V or less will be treated as a digital low level logic "0", while input signals that have a voltage level of 2.0V or more will be treated as a digital high level logic "1".

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The muting of audio signals being received by the PLC receiver module 122/132 is achieved by sending an appropriate signal through pin 7 of the connector 526. Pin 7 is active when there is a digital low level logic "0" signal present. The mute function is invoked, for example, through the multi-function stereo set 102 (Figure 1) sending an appropriate signal to pin 7 of the connector 526 of the PLC receiver module 122/132. When the mute function is invoked, the first speaker unit 104 (Figure 1) and the second speaker unit 106 (Figure 1) will stop emitting sound. For instance, the primary controller 144 (Figure 1) will invoke the mute function when the carrier frequency used to transmit audio signals is changed. The first speaker unit 104 (Figure 1) and the second speaker unit 106 (Figure 1) will stop emitting sound for the duration taken to select another carrier frequency.

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Pins 10 and 11 of the connector 526 serve as a serial interface for the PLC receiver module 122/132 to respectively receive and transmit UART signals. When the system 100 (Figure 1) is operated at the first or second speaker units 104 and 106 (Figure 1) end, an appropriate signal is sent back to the multi-function stereo set 102 via pin 11.

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It will be appreciated by a person skilled in the art that numerous variations and/or modifications may be made to the present invention as shown in the specific embodiments without departing from the spirit or scope of the invention as broadly described. The present embodiments are, therefore, to be considered in all respects to be illustrative and not restrictive.

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CLAIMS:

(93)

1. An audio system for transmitting audio signals through a power line comprising:
- 5 (a) a primary display unit;
- (b) one or more audio source components;
- (c) a power line communication transmitter module coupled to the power line, which
able to transmit audio signal from the audio source components into one of
different audio quality modes, using one of a plurality available carrier frequency
10 via the power line;
- (d) a primary controller with an user interface for activation through user input
communicates with the power line communication transmitter module in a duplex
manner for interrogating the transmission status of the radio frequency signal,
sending a control signal to the primary display unit to display the transmission
15 status for view by a user, instructing the transmitter module to change a different
carrier frequency to transmit audio signals based on user instruction; and selecting
audio source from the one or more audio source components;
- (e) a first speaker unit, having a first power line communication receiver module for
processing carrier frequency and extracting the audio signal from the carrier
20 frequency, coupled to the power line for outputting the audio signal;
whereby the power line communication transmitter module automatically selects
initial carrier frequency based on impedance characteristic of the power line for
transmission before transmitting the audio signal and transmits the audio signal in
highest possible audio quality mode, the transmitter module selects a different
25 carrier frequency instructed which capable of continuous transmitting the audio
signal in highest possible audio quality mode by the primary controller via
activation of the user interface based on user instruction when data transmission
errors arise due to the selected carrier frequency becomes unsuitable for
continuous transmission.
- 30
2. An audio system according to claim 1, further comprising a second speaker unit,
having a second power line communication receiver module for processing carrier
frequency and extracting the audio signal from the carrier frequency, coupled to
the power line for outputting the audio signal.

3. An audio system according to claims 1 and 2, further comprising a remote control sensor to receive signal to activate the primary controller from a remote control unit.
- 5 4. An audio system according to claims 1 to 3, wherein first speaker unit and/or second speaker unit further comprising a processor with an user interface to active the primary controller.
- 10 5. An audio system according to claim 4, wherein the first speaker unit and/or second speaker unit further comprising a remote control sensor to receive signal to activate the primary controller through the processor from a remote control unit.
- 15 6. An audio system according to claims 3 to 5, wherein the remote control unit further comprising a secondary display unit to provide visual indicators of operation status of the audio system from the signal received from the primary controller.
- 20 7. An audio system according to claims 1 to 6, wherein the power line communication transmitter module is electrically connected a surge absorber to protect the audio system from power fluctuation and power surge from the power line.
- 25 8. An audio system according to claims 1 to 7, wherein the power line communication receiver module is electrically connected a surge absorber to protect the audio system from power fluctuation and power surge from the power line.
- 30 9. An audio system according to claims 1 to 8, wherein the audio source components are a disc player and/or radio receiver.
10. An audio system according to claim 9, wherein the disc player is capable of reading disc in CD, DVD and/or MP3 format.

11. An audio system according to claims 1 and 9, wherein the audio source interface selected from the group consisting of a memory card reader, a portable source medium reader, an adaptor for connecting a portable hard disk and a connector for connecting to an external audio source.
- 5
12. An audio system according to claims 1 to 11, wherein the power line communication transmitter module is capable of transmitting a first and second audio signal comprising a left and right channel from same audio source.
- 10
13. An audio system according to claims 12, wherein the first speaker unit further comprising a left speaker and right speaker coupled to the first power line communication receiver module through a switch module to transmit the left and right channel from the same audio source.
- 15
14. An audio system according to claims 12, wherein the second speaker unit has a speaker coupled to the second power line communication receiver module through a mix module to transmit the left and right channel from the same audio source.
- 20
15. An audio system according to claims 2 to 11, wherein the power line communication transmitter module is capable of transmitting a first and second audio signal comprising audio from two different audio sources that the first speaker unit receives the first audio signal and the second speaker unit receives the second audio signal.
- 25
16. An audio system according to claims 1 to 15, wherein the primary controller is capable of instructing the power line communication transmitter module to check for the best carrier frequency for transmitting the audio signal upon user activation.
- 30
17. An audio system according to claims 1 to 16, wherein the carrier frequency is radio frequency.

18. An audio system according to claims 1 to 17, wherein the carrier frequency ranges from 2 MHz to 20 MHz.

19. An audio system according to claims 1 to 17, wherein the different audio quality
5 mode each has a corresponding sampling rate and bit length.