

METHOD AND SYSTEM FOR ADAPTIVE CONTROL OF TRANSMITTING-END GAIN OF LPO OPTICAL MODULE, AND OPTICAL MODULE

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] The present disclosure claims the priority to the Chinese patent application No. 2024116727683 filed with the Chinese Patent Office on November 21, 2024, and entitled “METHOD AND SYSTEM FOR ADAPTIVE CONTROL OF TRANSMITTING-END GAIN OF LPO OPTICAL MODULE, AND OPTICAL MODULE”, the contents of which are incorporated herein by reference in entirety.

TECHNICAL FIELD

[0002] The present disclosure relates to the technical field of optical communication, and specifically to a method and a system for adaptive control of transmitting-end gain of an LPO optical module, and an optical module.

BACKGROUND ART

[0003] Along with the rapid development of the optical communication industry, and driven by the enormous demand of 5G and artificial intelligence (AI) in recent years, the market demand of optical modules has rapidly grown. Data center network rate gradually develops from 100G, 200G, and 400G to 800G and 1.6T, and can even reach 3.2T in the near future. The expanding demand of data center optical networks rapidly feeds back to the supply side of optical modules, and the direct result is a rapid increase in the rate of optical modules. However, technical iteration is not merely doubling of numbers. After reaching stage of 400G rate, when solving the problem of improving data transmission rate, it also must face challenges brought by increased power consumption, required packaging manner, and optical module cost.

[0004] In an early stage, the power consumption of a 10G optical module is only about 1W, and with development to the present, the power consumption of an optical module at the present stage (400G and 800G) is basically in an energy consumption state above 10W. A sharp increase in the power consumption of the optical module also causes a rapid rise in the proportion of the optical module in the total power consumption of an entire device. The present proportion already reaches 40% or more of the total power consumption of the entire device, which brings a huge burden to energy utilization and the cost of an entire data center. For solving these problems, an industry performs exploration in multiple directions. A linear-drive pluggable optics (LPO) module is one direction in which the industry mainly focuses.

[0005] The LPO optical module adopts a linear-drive strategy. Through using a transimpedance amplifier (TIA) and a driver chip (Driver) which provide excellent linearity and equalization capability to replace a digital signal processor (DSP) or a clock and data recovery (CDR), defects of high energy consumption and high link latency of the optical module in the DSP or CDR solution are avoided, which further matches data communication

requirements of short distance, high bandwidth, low power consumption and low latency of a present data center.

[0006] Compared with a traditional optical module, the advantages of the LPO optical module are mainly provided in four aspects, including low power consumption, low cost, low latency, and easy maintenance. However, correspondingly, because of no intervention of the DSP and the CDR, linear driver inevitably has problems of an increased bit-error rate and an excessive insertion loss of the module channel. Especially, at different temperatures, if different switches require maintaining a low bit-error rate and low channel insertion loss, the present operation in the industry usually is that different devices perform individual matching for the LPO module through different finite impulse response (FIR) filters or various other parameters, which will be a large construction cost. Furthermore, a subsequent maintenance process also presents problems of difficult maintenance and gradually increasing cost. Therefore, for effectively reducing various costs, solving this series of difficulties from the root (an LPO-series optical module) is always one research direction of scientific research personnel.

[0007] Under the present optical-communication network conditions, the application of the LPO optical module is arranged as follows. A switch adjusts various parameters of the LPO optical module through an IIC bus and a parameter-adjustment protocol agreed with the manufacturer of the optical module, for matching data receiving and sending at another end. The present optimization manner of the LPO optical module is mainly provided through manually adjusting parameter-setting values together with setting parameters of the switch side under different data-transmission performance. Defects are provided as follows. (1) Traversal of parameter-setting values is difficult. Under the premise that any electrical-port parameter of a switch changes, each switch requires re-traversal of parameters of the optical module; otherwise, communication consistency cannot be guaranteed. Within an entire parameter-setting range, different parameter combinations of the switch require different parameter-setting values for achieving optimal output conditions. (2) The insertion loss of each port of the switch differs. If the insertion loss of different ports of different switches requires matching, traversal of parameter-setting values is also required; otherwise, handshake communication and communication efficiency between optical modules are affected. (3) Under different temperatures and insertion-loss conditions, manually adjusting the parameter-setting values hardly finds a balance point. Therefore, under the premise that each switch requires manual sorting and traversal configuration, the workload of any data center becomes a large-scale project that is extremely manpower-consuming and material-consuming. Moreover, expenses increase, and human errors and mistakes introduced by manual configuration cannot be ignored. These defects bring significant economic loss and negative influence to a client side.

[0008] Based on this, a technical problem urgently required to be solved at present is how to realize adaptive adjustment of transmitting-end output gain for reducing the insertion loss of optical-module channels.

SUMMARY

[0009] An objective of the present disclosure is to provide a method and a system for adaptive control of the transmitting-end gain of an LPO optical module, and an optical module. Through determining a comprehensive output amplitude, and comparing the comprehensive output amplitude with a target gain, and under the premise of synchronously adjusting a maximum-gain peak value under different insertion-loss conditions, adjustment of transmitting-end gain is transferred from manual operation to optical-module firmware. Through the firmware of the optical module, the matching and the adaptive-output operation of the transmitting-end gain are completed. A technical problem of how to realize adaptive adjustment of transmitting-end output gain for reducing insertion loss of an optical-module channel can be solved.

[0010] The present disclosure is implemented by the following technical solutions. An adaptive control method for transmitting-end gain of an LPO optical module is provided, which includes steps as follows: acquiring a maximum-gain peak value and an output-amplitude acquisition value of an LPO optical-module state machine under a normal-running state; performing a fitting calculation using the output-amplitude acquisition value and a peak-control lookup table to determine a comprehensive output amplitude; comparing the comprehensive output amplitude with a target gain; and performing an adaptive adjustment of a transmitting-end gain of the LPO optical module through a firmware of the optical module based on a comparison result and the maximum-gain peak value.

[0011] According to an optional embodiment, the maximum-gain peak value is obtained based on an insertion-loss condition of a current LPO optical-module channel and through the peak-control lookup table.

[0012] According to an optional embodiment, the peak-control lookup table divides the insertion-loss conditions into multiple levels, wherein each level corresponds to one maximum-gain peak value.

[0013] According to an optional embodiment, the step of acquiring a maximum-gain peak value and an output-amplitude acquisition value of an LPO optical-module state machine under a normal-running state comprises:

[0014] acquiring a maximum-gain peak value and an output-amplitude acquisition value of an LPO optical-module state machine under a normal-running state according to a preset sampling cycle period of the LPO optical module.

[0015] According to an optional embodiment, a frequency of the output-amplitude acquisition value is 18 GHz to 20 GHz.

[0016] According to an optional embodiment, the comprehensive output amplitude is expressed as follows:

[0017] $C = Kx * Value + Bx$,

[0018] where C represents the comprehensive output amplitude, Kx represents a slope corresponding to a level in the peak-control lookup table, $Value$ represents the output-amplitude acquisition value, Bx represents an intercept corresponding to the level in the peak-control lookup table.

[0019] According to an optional embodiment, before the step of acquiring a maximum-gain peak value and an output-amplitude acquisition value of an LPO optical-module state machine under a normal-running state, the method further comprises:

[0020] enabling the state machine to enter an initialization state after powering on the LPO optical module, and enabling the state machine to switch to a normal-running state after a configuration of an initial transmitting-end gain and a maximum-gain peak value.

[0021] According to an optional embodiment, the step of performing an adaptive adjustment of a transmitting-end gain of the LPO optical module based on a comparison result and the maximum-gain peak value specifically comprises:

[0022] reducing, in response to the comprehensive output amplitude being greater than the target gain, the transmitting-end gain in a stepwise manner until a step stopping condition is satisfied, and adjusting the maximum-gain peak value synchronously, wherein the step stopping condition is that an absolute deviation between a real-time acquired output-amplitude acquisition value and the target gain is smaller than a preset threshold.

[0023] According to an optional embodiment, the step of performing an adaptive adjustment of a transmitting-end gain of the LPO optical module based on a comparison result and the maximum-gain peak value specifically comprises:

[0024] increasing, in response to the comprehensive output amplitude being smaller than the target gain, the transmitting-end gain in a stepwise manner until the step stopping condition is satisfied, and adjusting the maximum-gain peak value synchronously.

[0025] The present disclosure further provides a system for adaptive control of transmitting-end gain of an LPO optical module, including:

[0026] a data-acquisition module, configured to acquire a maximum-gain peak value and an output-amplitude acquisition value of an LPO optical-module state machine under a normal-running state;

[0027] a calculation module, configured to perform a fitting calculation using the output-amplitude acquisition value and a peak-control lookup table to determine a comprehensive output amplitude;

[0028] a comparison module, configured to compare the comprehensive output amplitude with a target gain; and

[0029] an adjustment module, configured to perform an adaptive adjustment of a transmitting-end gain of the LPO optical module through a firmware of the optical module based on a comparison result and the maximum-gain peak value.

[0030] The present disclosure further provides an LPO optical module that applies the method for adaptive control of the transmitting-end gain of an LPO optical module described above.

[0031] The method and the system for adaptive control of transmitting-end gain of an LPO optical module and the optical module provided by the present disclosure offer at least the following advantages and beneficial effects. In the present disclosure, based on the output-amplitude acquisition value, a comprehensive output amplitude is determined, and the comprehensive output amplitude is compared with a target gain; and under a premise of synchronously adjusting a maximum-gain peak value under different insertion-loss conditions, adjustment of transmitting-end gain is transferred from manual operation to the firmware of the optical module. Through the firmware of the optical module, matching and adaptive-output operations of the transmitting-end gain are completed. The adaptive matching to different switch ports and different high- and low-temperature environments can

be enabled, which can effectively improve matching efficiency between the LPO optical module and the switch, and reduce unnecessary labor cost, maintenance cost, and various errors and mistakes introduced by manual commissioning at the application end.

BRIEF DESCRIPTION OF DRAWINGS

[0032] FIG. 1 is a schematic flow diagram of a method for adaptive control of transmitting-end gain of an LPO optical module provided in an embodiment of the present disclosure; and [0033] FIG. 2 is a schematic diagram of an adaptive control of a transmitting-end gain provided in an embodiment of the present disclosure.

DETAILED DESCRIPTION OF EMBODIMENTS

[0034] In order to make the objective, technical solutions, and advantages of the embodiments of the present disclosure clearer, the following description will provide a clear and comprehensive explanation of the technical solutions in the embodiments of the present disclosure with reference to the drawings of the present disclosure. Clearly, the described embodiments are part of the embodiments of the present disclosure and not the entire embodiments. The components of embodiments of the present disclosure, which are generally described and illustrated in the drawings herein can be arranged and designed in a variety of different configurations.

[0035] FIG. 1 is a schematic flow diagram of a method for adaptive control of transmitting-end gain of an LPO optical module provided in an embodiment of the present disclosure. Referring to FIG. 1, the adaptive control method for the transmitting-end gain includes steps as follows.

[0036] S101: acquiring a maximum-gain peak value and an output-amplitude acquisition value of an LPO optical-module state machine under a normal-running state.

[0037] Optionally, a maximum-gain peak value and an output-amplitude acquisition value of an LPO optical-module state machine under a normal-running state can be acquired according to a preset sampling-cycle period of the LPO optical module.

[0038] In some embodiments, a preset sampling-cycle period of the LPO optical module can be flexibly configured according to an actual application scenario, and no specific value is limited herein. It can be understood that, by collecting a maximum-gain peak value and an output-amplitude acquisition value of an LPO optical-module state machine under a normal-running state according to a preset sampling-cycle period of the LPO optical module, real-time acquisition of the maximum-gain peak value and the output-amplitude acquisition value can be achieved, thereby enabling subsequent real-time matching.

[0039] S102: performing a fitting calculation using the output-amplitude acquisition value and a peak-control lookup table to determine a comprehensive output amplitude.

[0040] S103: comparing the comprehensive output amplitude with a target gain.

[0041] S104: performing an adaptive adjustment of a transmitting-end gain of the LPO optical module through a firmware of the optical module based on a comparison result and the maximum-gain peak value.

[0042] After powering on a linear-drive pluggable optics (LPO) module, the state machine enters an initialization state. In this initialization state, the state machine is configured with an

initial transmitting-end gain, a maximum-gain peak value, and other adjustment parameters, and then switches to a normal-running state. The LPO optical module thereafter enters a normal main loop. The initial transmitting-end gain and the maximum-gain peak value are general values configured based on a combination of target customer application scenarios and physical characteristics of the module.

[0043] In the normal-running state, each main loop collects one output-amplitude acquisition value of the LPO optical module to maintain real-time performance of subsequent fitting calculation and gain-feedback adjustment.

[0044] In an optional implementation of the embodiment, a frequency of the output-amplitude acquisition value is 18 GHz to 20 GHz, wherein the value at 20 GHz is referred to as a 20GPKD value, and the output-amplitude acquisition value at the frequency of 20 GHz serves as the dominant value.

[0045] In one optional implementation of the embodiment, the peak-control lookup table divides the insertion-loss conditions into multiple levels, wherein each level corresponds to one maximum-gain peak value.

[0046] Further, each main loop synchronously obtains one maximum-gain peak value, Peaking Ctrl, of the LPO optical module. In an optional implementation of the embodiment, the maximum-gain peak value is obtained based on an insertion-loss condition of a current LPO optical-module channel by querying a peak-control lookup table (Peaking Ctrl LUT).

[0047] It should be noted that the peak-control lookup table, i.e., Peaking Ctrl LUT, is lookup table generated for each LPO optical module before leaving a factory, wherein the lookup table is formed according to physical characteristics of the LPO optical module within a preset temperature range (−40°C to 85°C) and includes maximum-gain peak values corresponding to transmitting ends of the optical module under various temperature levels.

[0048] It should be noted that, in one possible implementation, the peak-control lookup table divides all insertion-loss conditions into multiple levels, for example, 20 levels. For each level, a maximum-gain peak value required to be set under the level is calculated, and the maximum-gain peak value is a range-control value.

[0049] The comprehensive output amplitude is determined based on the fitting calculation using the output-amplitude acquisition value and the peak-control lookup table. The expression of the comprehensive output amplitude is as follows:

[0050] $C = Kx * Value + Bx$

[0051] where C represents the comprehensive output amplitude, Kx represents a slope corresponding to a level in the peak-control lookup table, $Value$ represents the output-amplitude acquisition value, and Bx represents an intercept corresponding to the level in the peak-control lookup table. The Kx and Bx can be calculated from the peak-control lookup table.

[0052] It should be noted that, in one possible implementation, the peak-control lookup table divides a preset temperature range (from a low temperature of −25°C to a high temperature of 75°C) into multiple levels. For example, each 5°C is divided into one level, thereby dividing the preset temperature range into 20 levels. When the temperature exceeds the minimum of −25°C and the maximum of 75°C, the slope of a linear fit is set to 0, and the intercept remains unchanged from the previous level. By dividing temperature into levels, the

influence of different insertion-loss conditions can be reduced, and an excessive burden on the operation and calculation of module firmware is avoided.

[0053] Further, the comprehensive output amplitude C is compared with the target gain (target VGAIN value), and the firmware of the optical module adaptively adjusts the transmitting-end gain of the LPO optical module based on the comparison result and in combination with the maximum-gain peak value. The adaptive control of the transmitting-end gain is shown in FIG. 2.

[0054] In an implementation of the embodiment, the step of performing an adaptive adjustment of a transmitting-end gain of the LPO optical module based on a comparison result and the maximum-gain peak value specifically comprises:

[0055] reducing, in response to the comprehensive output amplitude being greater than the target gain, the transmitting-end gain in a stepwise manner, and applying negative feedback of the comprehensive output amplitude to a VGAIN value until a step stopping condition is satisfied, and adjusting the maximum-gain peak value synchronously, wherein the step stopping condition is that an absolute deviation between a real-time acquired 20GPKD value and the target VGAIN value is smaller than a preset threshold; increasing, in response to the comprehensive output amplitude being smaller than the target gain, the transmitting-end gain in a stepwise manner, and applying positive feedback of the comprehensive output amplitude to the VGAIN value until the step stopping condition is satisfied, and adjusting the maximum-gain peak value synchronously; and switching the state machine to a normal-running state and performing calculation and monitoring of the 20GPKD value and the target VGAIN value under the normal-running state after the step stopping condition is satisfied.

[0056] In summary, the present disclosure uses the output-amplitude acquisition value as a basis, determines a comprehensive output amplitude, and compares the comprehensive output amplitude with a target gain. Under a premise of synchronously adjusting a maximum-gain peak value under different insertion-loss conditions, adjustment of the transmitting-end gain is transferred from manual operation to the firmware of the optical module. Through the firmware of the optical module, matching and adaptive-output operations of the transmitting-end gain are completed. This enables adaptive matching to different switch ports and different high- and low-temperature environments, which effectively improves matching efficiency between the LPO optical module and the switch, and reduces unnecessary labor cost, maintenance cost, and various errors and mistakes introduced by manual commissioning at the application side.

[0057] Based on the embodiments described above, the present disclosure provides a system for adaptive control of transmitting-end gain of an LPO optical module, and the system includes a data-acquisition module, a calculation module, a comparison module, and an adjustment module.

[0058] The data-acquisition module is configured to acquire a maximum-gain peak value and an output-amplitude acquisition value of an LPO optical-module state machine under a normal-running state. The calculation module is configured to perform a fitting calculation using the output-amplitude acquisition value and a peak-control lookup table to determine a comprehensive output amplitude. The comparison module is configured to compare the comprehensive output amplitude with a target gain. The adjustment module is configured to

perform an adaptive adjustment of a transmitting-end gain of the LPO optical module through a firmware of the optical module based on a comparison result and the maximum-gain peak value.

[0059] Based on the embodiments described above, the present disclosure provides an LPO optical module that applies the adaptive control method for the transmitting-end gain of an LPO optical module described above.

[0060] The above are only optional embodiments of the present disclosure, which are not intended to limit, and the present disclosure may have various changes and variations for those skilled in the art. Any modification, equivalent substitution, improvement, etc., made within the spirit and principles of the present disclosure shall be included in the scope of protection of the present disclosure.

INDUSTRIAL PRACTICALITY

[0061] The above solutions can enable adaptive matching to different switch ports and different high- and low-temperature environments. Compared to the existing manual configuration method, the present disclosure can effectively improve matching efficiency between the LPO optical module and the switch, and reduce unnecessary labor cost, maintenance cost, and various errors and mistakes introduced by manual commissioning at the application end.

CLAIMS

1. A method for adaptive control of transmitting-end gain of an LPO optical module, comprising following steps:

acquiring a maximum-gain peak value and an output-amplitude acquisition value of an LPO optical-module state machine under a normal-running state;

performing a fitting calculation using the output-amplitude acquisition value and a peak-control lookup table to determine a comprehensive output amplitude;

comparing the comprehensive output amplitude with a target gain; and

performing an adaptive adjustment of the transmitting-end gain of the LPO optical module through a firmware of the optical module based on a comparison result and the maximum-gain peak value.
2. The method for adaptive control of transmitting-end gain of an LPO optical module according to claim 1, wherein the maximum-gain peak value is obtained based on insertion-loss conditions of a current LPO optical-module channel and through the peak-control lookup table.
3. The method for adaptive control of transmitting-end gain of an LPO optical module according to claim 2, wherein the peak-control lookup table divides the insertion-loss conditions into multiple levels, and each level corresponds to one maximum-gain peak value.
4. The method for adaptive control of transmitting-end gain of an LPO optical module according to claim 1, wherein the step of acquiring a maximum-gain peak value and an output-amplitude acquisition value of an LPO optical-module state machine under a normal-running state comprises:

acquiring the maximum-gain peak value and the output-amplitude acquisition value of the LPO optical-module state machine under the normal-running state according to a preset sampling-cycle period of the LPO optical module.
5. The method for adaptive control of transmitting-end gain of an LPO optical module according to claim 1, wherein a frequency of the output-amplitude acquisition value is 18 GHz to 20 GHz.

6. The method for adaptive control of transmitting-end gain of an LPO optical module according to claim 1, wherein the comprehensive output amplitude is expressed as follows:

$$C = Kx * Value + Bx$$

where C represents the comprehensive output amplitude, Kx represents a slope corresponding to a level in the peak-control lookup table, $Value$ represents the output-amplitude acquisition value, and Bx represents an intercept corresponding to the level in the peak-control lookup table.

7. The method for adaptive control of transmitting-end gain of an LPO optical module according to claim 1, wherein before the step of acquiring a maximum-gain peak value and an output-amplitude acquisition value of an LPO optical-module state machine under a normal-running state, the method further comprises:

enabling the state machine to enter an initialization state after powering on the LPO optical module, and enabling the state machine to switch to the normal-running state after a configuration of an initial transmitting-end gain and a maximum-gain peak value.

8. The method for adaptive control of transmitting-end gain of an LPO optical module according to claim 1, wherein the step of performing an adaptive adjustment of the transmitting-end gain of the LPO optical module based on a comparison result and the maximum-gain peak value comprises:

reducing the transmitting-end gain in a stepwise manner in response to the comprehensive output amplitude being greater than the target gain until a step stopping condition is satisfied, and adjusting the maximum-gain peak value synchronously, wherein the step stopping condition is that an absolute deviation between a real-time acquired output-amplitude acquisition value and the target gain is smaller than a preset threshold.

9. The method for adaptive control of transmitting-end gain of an LPO optical module according to claim 8, wherein the step of performing an adaptive adjustment of the transmitting-end gain of the LPO optical module based on a comparison result and the maximum-gain peak value comprises:

increasing the transmitting-end gain in a stepwise manner until the step stopping condition is satisfied, in response to the comprehensive output amplitude being smaller than the target gain; and adjusting the maximum-gain peak value synchronously.

10. A system for adaptive control of transmitting-end gain of an LPO optical module, comprising:

a data-acquisition module, configured to acquire a maximum-gain peak value and an output-amplitude acquisition value of an LPO optical-module state machine under a normal-running state;

a calculation module, configured to perform a fitting calculation using the output-amplitude acquisition value and a peak-control lookup table to determine a comprehensive output amplitude;

a comparison module, configured to compare the comprehensive output amplitude with a target gain; and

an adjustment module, configured to perform an adaptive adjustment of the transmitting-end gain of the LPO optical module through a firmware of the optical module based on a comparison result and the maximum-gain peak value.

11. An LPO optical-module, applied to the method for adaptive control of transmitting-end gain of an LPO optical module according to any one of claims 1 to 9.