Title: UNIVERSAL HOST MODULE FOR A PLUGGABLE OPTICAL TRANSMITTER

Abstract: A method includes tuning a host module to a reference module standard; and adjusting each of a plurality of plug-gable optical modules coupled to the host module to mimic the reference module standard for a set of load conditions. An apparatus includes a host module tuned to a reference module standard; and a plurality of pluggable optical modules coupled to the host module, wherein each of the plurality of pluggable optical modules mimics the reference standard for a specific set of load conditions.
DESCRIPTION

Universal Host Module for a Pluggable Optical Transmitter

BACKGROUND

Small form factor pluggable optical modules (SFF, SFP, SFP+, XFP etc.) are ubiquitous in fiber-optic transmission systems using digital On-Off-Keying (OOK) modulation formats. Standards have been developed (Ethernet, SONET, Fiber Channel, GPON etc.) such that any pluggable optical module governed by a standard can be used interchangeably with any digital host module (Packet optical switches, Routers, Optical Line Terminal etc.) within that same standard. This is relatively easy to do with OOK modulation since laser non-linearity does not significantly affect transmission performance. However, with higher order modulation formats, such as Phase-Shift-Keying (PSK), Quadrature Amplitude Modulation (QAM) and Amplitude Modulation/Vestigial Side-Band (AM-VSB), the laser non-linear effects can be quite significant that fiber optic transmission is limited to only a small set of conditions.

SUMMARY

There is a need for the following embodiments of the present disclosure. Of course, the present disclosure is not limited to these embodiments.

According to an embodiment of the present disclosure, a process comprises: tuning a host module to a reference module standard; and adjusting each of a plurality of pluggable optical modules coupled to the host module to mimic the reference module standard for a set of load conditions. According to another embodiment of the present disclosure, a machine comprises: a host module tuned to a reference module standard; and a plurality of pluggable optical modules coupled to the host module, wherein each of the plurality of pluggable optical modules mimics the reference standard for a specific set of load conditions.

These, and other, embodiments of the present disclosure will be better appreciated and understood when considered in conjunction with the following description and the accompanying drawings. It should be understood, however, that the following description, while indicating various embodiments of the present disclosure and numerous specific details thereof, is given for the purpose of illustration and does not imply limitation. Many substitutions, modifications, additions and/or rearrangements may be made within the scope...
of embodiments of the present disclosure, and embodiments of the present disclosure include all such substitutions, modifications, additions and/or rearrangements.

**BRIEF DESCRIPTION OF THE DRAWINGS**

The drawings accompanying and forming part of this specification are included to depict certain embodiments of the present disclosure. A clearer concept of the embodiments described in this application will be readily apparent by referring to the exemplary, and therefore nonlimiting, embodiments illustrated in the drawings (wherein identical reference numerals (if they occur in more than one view) designate the same elements). The described embodiments may be better understood by reference to one or more of these drawings in combination with the following description presented herein. It should be noted that the features illustrated in the drawings are not necessarily drawn to scale.

FIG. 1 is block schematic view of a universal host module with multiple compensation circuits and pluggable optical modules, representing an embodiment of the present disclosure.

FIG. 2 is a block schematic view of (a) reference module (b) pluggable optical module, representing an embodiment of the present disclosure.

**DETAILED DESCRIPTION**

Embodiments presented in the present disclosure and the various features and advantageous details thereof are explained more fully with reference to the nonlimiting embodiments that are illustrated in the accompanying drawings and detailed in the following description. Descriptions of well known signal processing techniques, components and equipment are omitted so as not to unnecessarily obscure the embodiments of the present disclosure in detail. It should be understood, however, that the detailed description and the specific examples are given by way of illustration only and not by way of limitation. Various substitutions, modifications, additions and/or rearrangements within the scope of the underlying inventive concept will become apparent to those skilled in the art from this disclosure.

Embodiments of the invention relate to transmission of analog and/or digital signals over fiber optics. More specifically, some embodiments of the invention relate to small form factor pluggable modules for transmission systems such as, but not limited to, CATV systems. The
disclosure of this application is marginally related to copending U.S. Ser. Nos. 13/672,712, filed November 9, 2012, 13/672,714, filed November 9, 2012, 13/672,716, filed November 9, 2012, 13/672,717, filed November 9, 2012, 13/672,718, filed November 9, 2012 the entire contents of all of which are hereby expressly incorporated by reference for all purposes.

Optical devices using higher order modulation formats can be fine-tuned with specialized circuitry to allow usage under a wide variety of conditions. However, this comes at the expense of large size due to special circuitry that precludes the adoption of standardized pluggable optical modules when transmitting data with high order modulation formats.

Embodiments of the invention can include a method whereby this limitation of large size can be overcome by creating a pluggable optical module that mimics the behavior of a reference optical module. Meanwhile, the host module can be tuned to the reference module. Thus, any pluggable module can be used interchangeably with any host module.

Referring to Figure 1, embodiments of the invention can include a host module 100 that includes for each pluggable optical module a plurality of pre-distortion circuits 110 and a plurality of non-linear fiber-optic phenomena suppression circuits 120 to universally tune a pluggable optical transmitter (individually tune each module slot or bay to a reference optical module). This plurality of circuits can be provided for each pluggable module 130. The host module can be coupled to any number of pluggable modules that take (accept) a broadband RF input signal which can include some number of analog channels and some number of QAM channels to transmit video, for example, DOCSIS (data over cable service interface specification), telephony or digital content.

The pluggable optical module can conform to existing SFP, orXFP or similar form factors, but is not limited to only these standards. The pluggable module can be of standard 1310nm, 1550nm, CWDM or DWDM wavelengths, but is not limited to these. The optical device inside the reference and/or pluggable optical module(s) can be a directly modulated laser (DML), electro-absorption modulated laser (EML), an externally modulated laser (XML) with a Mach-Zehnder modulator or phase modulator, but is not limited to these. The host module can be a physical interface card that plugs into an fiber optic transmission platform such as an OLT (optical line termination), HFC chassis module, edge QAM card or any downstream line card that carries or has inputs/outputs for the broadband input signal in the electrical domain.

Referring to Figure 2(a), the host module with the plurality of pre-distortion circuits can be tuned to a (standard) reference laser module 220 for a specific set of load conditions. Referring to Figure 2(b), a pluggable optical transmitter module 240 can be made to mimic...
(behave the same as) (exhibit the performance characteristics of) such a (standard)
reference laser module. This means parameters of the pluggable optical transmitter such as
laser chirp, second order, third order or higher order distortions, time dependant distortions,
time independent distortions, etcetera under a set of load conditions would behave the same
as the reference laser module.

The pluggable module can have a chirp compensation circuit 250 which could add a signal
out-of-band to the desired transmission signal such that the pluggable optical transmitter
module would behave the same as the reference module. In addition, other circuits 260
could add or subtract in-band distortion signal(s) of the correct magnitude and phase such
that the pluggable optical module would mimic the reference module. Thus, when the
pluggable module is inserted into the host module, the performance can be the same as the
reference laser module under that same broadband analog input signal. Since the host
module is tuned to a reference module and the pluggable module is made to behave as the
reference then any host and any pluggable module can be paired together to achieve the
desired performance under a set of load conditions.

Definitions

The term mimic is intended to mean behave the same as, or exhibit the performance
characteristics of, a standard reference laser module under a specific set of load conditions.

The terms program and/or software and/or the phrases computer program and/or computer
software are intended to mean a sequence of instructions designed for execution on a
computer system (e.g., a program and/or computer program, may include a subroutine, a
function, a procedure, an object method, an object implementation, an executable
application, an applet, a servlet, a source code, an object code, a shared library/dynamic
load library and/or other sequence of instructions designed for execution on a computer or
computer system). The phrase radio frequency (RF) is intended to mean frequencies less
than or equal to approximately 300 GHz as well as the infrared spectrum.

The term substantially is intended to mean largely but not necessarily wholly that which is
specified. The term approximately is intended to mean at least close to a given value (e.g.,
within 10% of). The term generally is intended to mean at least approaching a given state.
The term coupled is intended to mean connected, although not necessarily directly, and not
necessarily mechanically.
The terms first or one, and the phrases at least a first or at least one, are intended to mean the singular or the plural unless it is clear from the intrinsic text of this document that it is meant otherwise. The terms second or another, and the phrases at least a second or at least another, are intended to mean the singular or the plural unless it is clear from the intrinsic text of this document that it is meant otherwise. Unless expressly stated to the contrary in the intrinsic text of this document, the term or is intended to mean an inclusive or and not an exclusive or. Specifically, a condition A or B is satisfied by any one of the following: A is true (or present) and B is false (or not present), A is false (or not present) and B is true (or present), and both A and B are true (or present). The terms a and/or an are employed for grammatical style and merely for convenience.

The term plurality is intended to mean two or more than two. The term any is intended to mean all applicable members of a set or at least a subset of all applicable members of the set. The term means, when followed by the term "for" is intended to mean hardware, firmware and/or software for achieving a result. The term step, when followed by the term "for" is intended to mean a (sub)method, (sub)process and/or (sub)routine for achieving the recited result. Unless otherwise defined, all technical and scientific terms used herein have the same meaning as commonly understood by one of ordinary skill in the art to which this present disclosure belongs. In case of conflict, the present specification, including definitions, will control.

The described embodiments and examples are illustrative only and not intended to be limiting. Although embodiments of the present disclosure can be implemented separately, embodiments of the present disclosure may be integrated into the system(s) with which they are associated. All the embodiments of the present disclosure disclosed herein can be made and used without undue experimentation in light of the disclosure. Embodiments of the present disclosure are not limited by theoretical statements (if any) recited herein. The individual steps of embodiments of the present disclosure need not be performed in the disclosed manner, or combined in the disclosed sequences, but may be performed in any and all manner and/or combined in any and all sequences. The individual components of embodiments of the present disclosure need not be combined in the disclosed configurations, but could be combined in any and all configurations.

Various substitutions, modifications, additions and/or rearrangements of the features of embodiments of the present disclosure may be made without deviating from the scope of the underlying inventive concept. All the disclosed elements and features of each disclosed embodiment can be combined with, or substituted for, the disclosed elements and features of every other disclosed embodiment except where such elements or features are mutually
exclusive. The scope of the underlying inventive concept as defined by the appended claims and their equivalents cover all such substitutions, modifications, additions and/or rearrangements.

The appended claims are not to be interpreted as including means-plus-function limitations, unless such a limitation is explicitly recited in a given claim using the phrase(s) "means for" and/or "step for." Subgeneric embodiments of the invention are delineated by the appended independent claims and their equivalents. Specific embodiments of the invention are differentiated by the appended dependent claims and their equivalents.
What is claimed is:

1. A method, comprising:
   tuning a host module to a reference module standard; and
   adjusting each of a plurality of pluggable optical modules coupled to the host module to mimic the reference module standard for a set of load conditions.

2. The method of claim 1, wherein each of the plurality of pluggable optical modules includes a pluggable optical transmitter module whose performance parameters including laser chirp, second order distortions, third order distortions, time dependent distortions, time independent distortions respond the same as the reference laser module under the set of load conditions.

3. An apparatus, comprising:
   a host module tuned to a reference module standard; and
   a plurality of pluggable optical modules coupled to the host module, wherein each of the plurality of pluggable optical modules mimics the reference standard for a specific set of load conditions.

4. The apparatus of claim 3, wherein for each of the plurality of pluggable optical modules the host module includes a pre-distortion circuit and a non-linear fiber suppression circuit to individually tune each of the plurality of pluggable optical modules to the reference standard.

5. The apparatus of claim 3, wherein for each of the plurality of pluggable optical modules the host module includes a broadband RF signal input and an optical output.

6. The apparatus of claim 3, wherein each of the pluggable optical modules includes an optical device selected from the group consisting of a directly modulated laser (DML), an
electro-absorption modulated laser (EML) or an externally modulated laser (XML) with a Mach-Zehnder modulator or phase modulator

7. The apparatus of claim 3, wherein each of the pluggable optical modules includes a chirp compensation circuit to add a signal out-of-band to the desired transmission signal such that the pluggable optical transmitter module would behave the same as the reference module.

8. The apparatus of claim 3, wherein each of the pluggable optical modules includes a distortion mimicker circuit to add or subtract in-band distortion signal(s) of the correct magnitude and phase such that the pluggable optical module would mimic the reference module.

9. The apparatus of claim 3, further comprising a physical interface card coupled to the host module.

10. A device/method substantially as herein described.
**A. CLASSIFICATION OF SUBJECT MATTER**

INV. H04B10/572

**B. FIELDS SEARCHED**

Minimum documentation searched (classification system followed by classification symbols)

H04B H04J

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

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<td>EP 0 435 125 A2 (NEC CORP [JP]) 3 July 1991 (1991-07-03) column 1, line 49 - column 2, line 2 column 3, line 37 - column 4, line 45</td>
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