IN-BAND OPTICAL INTERFERENCE MITIGATION FOR DIRECT-DETECTION OPTICAL COMMUNICATION SYSTEMS

RELATED APPLICATIONS

[0001] This application claims priority to U.S. Patent Application No. 14/991,826, titled "IN-BAND OPTICAL INTERFERENCE MITIGATION FOR DIRECT-DETECTION OPTICAL COMMUNICATION SYSTEMS ," and filed January 8, 2016, the entire contents of which are hereby incorporated by reference.

TECHNICAL FIELD

[0002] This disclosure relates to the field of communication networks, and in particular to optical transceivers.

DESCRIPTION OF THE RELATED TECHNOLOGY

[0003] Communication systems, such as optical communication systems, include transmitters and receivers for communicating data over communication links. In some implementations, reflections caused by optical components such as connectors used in optical links can interfere with the original optical signals being transmitted between transmitters and receivers over the optical link.

[0003a] US 2014/308046 A1 teaches systems and methods for optical multi-path interference (MPI) compensation, wherein a mean MPI signal representing a mean amplitude of the MPI in an input signal is generated and subtracted from a first estimate of transmitted amplitude of the input signal to generate a mean MPI compensated estimate of transmitted amplitude. The mean MPI compensated estimate of transmitted amplitude is sliced to generate a decision of transmitted amplitude of the input signal. The mean MPI signal can be generated using a mean MPI feedback loop or using an iterative feed-forward process. Alternatively, mean MPI levels corresponding to respective transmitted intensity levels are generated and used to control slice levels of a slicer in order to compensate for MPI.

[0003b] WO 2015/043431 A1 teaches a system and method for improving reception of direct detection optical signals, wherein a method for optical transmission includes bit loading and power loading, with a digital signal processor (DSP), transmission bits of an orthogonal frequency-division multiplexing (OFDM) signal; calculating, with the DSP, a

signal-signal beat interference (SSBI) component of the bit and power loaded OFDM signal by modulating each subcarrier with a symbol; and subtracting, with the DSP, the calculated SSBI component from the bit and power loaded OFDM signal.

SUMMARY

[0004] According to one aspect, the subject matter described in this disclosure relates to an optical receiver for receiving an optical signal. The receiver includes at least one photo detector, an analog to digital converter, and a digital signal processor. The at least one photo detector is configured to generate a first electrical analog receiver signal in response to receiving an optical signal, the optical signal including a modulated optical signal and a noise optical signal, wherein the noise signal includes a reflected optical signal. The analog to digital converter is configured to receive the first electrical analog receiver signal and generate a corresponding first digital receiver signal. The digital signal processor is configured to subtract a data signal from the first digital receiver signal to generate an intermediate digital signal, wherein the digital signal processor determines the data signal from the first digital receiver signal. The digital signal processor is further configured to determine a frequency offset of an interference signal from the intermediate digital signal, the frequency offset of the interference signal indicative of the difference between the carrier frequencies of the modulated optical signal and the noise optical signal. The digital signal processor is also configured to filter the first digital receiver signal using a notch filter having a center frequency and bandwidth substantially equal to the frequency offset and a bandwidth, respectively, of the interference signal to generate a filtered digital receiver signal.

[0005] According to another aspect, the subject matter described in this disclosure relates to an optical receiver for receiving an optical signal. The receiver includes at least one photo detector, an analog to digital converter and a digital signal processor. The at least one photo detector is configured to generate a first electrical analog receiver signal in response to receiving an optical signal, the optical signal including a modulated optical signal and a noise optical signal, wherein the noise signal includes a reflected optical signal. The analog to digital converter is configured to receive the first electrical analog signal and generate a corresponding first digital receiver signal. The digital signal processor is configured to subtract a data signal from the first digital receiver signal to generate an intermediate digital signal, wherein the digital signal processor determines the data signal from the first digital receiver signal. The digital signal processor is further configured to determine a frequency

offset of an interference signal from the intermediate digital signal, the frequency offset of the interference signal indicative of the difference between the carrier frequencies of the modulated optical signal and the noise optical signal. The digital signal processor is also configured to filter the intermediate digital signal using a filter having a frequency and bandwidth equal to the frequency offset and a bandwidth, respectively, of the interference signal to generate an estimated interference signal. The digital signal processor is further configured to subtract the estimated interference signal from the first digital receiver signal to generate an interference suppressed digital receiver signal.

[0006] According to another aspect, the subject matter described in this disclosure relates to an optical transmitter including a laser configured to generate an optical signal having a carrier frequency. The transmitter further includes a modulator for modulating the carrier frequency with a data signal to generate a modulated optical signal. The transmitter also includes a laser tuner configured to tune the carrier frequency of the laser. The transmitter further includes a processor configured to receive a frequency offset of an interference signal from a receiver, the frequency offset of the interference signal indicative of the difference between an optical signal received at the receiver and a noise optical signal, wherein the noise optical signal includes a reflected optical signal. The processor is further configured to in response to receiving the frequency offset, dynamically compare the frequency offset with a bandwidth of the modulated optical signal; and based on the frequency offset being less than the bandwidth, control the laser tuner to tune the carrier frequency of the laser such that the received frequency offset is greater than the bandwidth.

CLAIMS

What is claimed is:

1. An optical receiver (110, 300) for receiving an optical signal, comprising:
   at least one photo detector (302) configured to generate a first electrical analog receiver signal in response to receiving an optical signal, the optical signal including a modulated optical signal and a noise optical signal, wherein the noise signal includes a reflected optical signal;
   an analog to digital converter (304) configured to receive the first electrical analog receiver signal and generate a corresponding first digital receiver signal; and
   a digital signal processor (154) configured to:
      subtract a data signal from the first digital receiver signal to generate an intermediate digital signal, wherein the digital signal processor determines the data signal from the first digital receiver signal;
      determine a frequency offset of an interference signal from the intermediate digital signal, the frequency offset of the interference signal indicative of the difference between the carrier frequencies of the modulated optical signal and the noise optical signal; and
      filter the first digital receiver signal using a notch filter (306) having a center frequency and bandwidth substantially equal to the frequency offset and a bandwidth, respectively, of the interference signal to generate a filtered digital receiver signal.

2. The optical receiver of claim 1, wherein the digital signal processor is further configured to:
   equalize the filtered digital receiver signal to carry out correction for at least one of optical attenuation and chromatic dispersion to generate an equalized digital receiver signal; and
   utilize the equalized digital receiver signal to generate the data signal.

3. The optical receiver of claim 1, wherein the frequency offset of the interference signal is substantially equal to zero.

4. The optical receiver of claim 1, wherein the frequency offset of the interference signal is less than a bandwidth of the modulated optical signal.

5. The optical receiver of claim 1, wherein the noise optical signal constitutes a reflection of the modulated optical signal, the reflection occurring over an optical link over which the optical signal is received.

6. The optical receiver of claim 1, wherein the noise optical signal constitutes a reflection of another optical signal transmitted by a transmitter other than the one transmitting the modulated optical signal, the reflection occurring over a bi-directional optical link over which both the another optical signal and the modulated optical signal are communicated.

7. The optical receiver of claim 1, wherein the digital signal processor is configured to determine the frequency offset of an interference signal from the intermediate digital signal based on a result of a fast-Fourier-transform of the intermediate signal.

8. An optical receiver (110, 400, 500) for receiving an optical signal, comprising:
at least one photo detector (402, 502) configured to generate a first electrical analog receiver signal in response to receiving an optical signal, the optical signal including a modulated optical signal and a noise optical signal, wherein the noise signal includes a reflected optical signal;
an analog to digital converter (404, 504) configured to receive the first electrical analog receiver signal and generate a corresponding first digital receiver signal; and
a digital signal processor configured to:
subtract a data signal from the first digital receiver signal to generate an intermediate digital signal, wherein the digital signal processor determines the data signal from the first digital receiver signal;
determine a frequency offset of an interference signal from the intermediate digital signal, the frequency offset of the interference signal indicative of the difference between the carrier frequencies of the modulated optical signal and the noise optical signal;

filter the intermediate digital signal using a filter (420, 520) having a frequency and bandwidth equal to the frequency offset and a bandwidth, respectively, of the interference signal to generate an estimated interference signal; and

subtract the estimated interference signal from the first digital receiver signal to generate an interference suppressed digital receiver signal.

9. The optical receiver of claim 8, wherein the digital signal processor is further configured to:

de-serialize the interference suppressed digital receiver signal to generate data blocks; and

decode the data blocks to generate decoded data.

10. The optical receiver of claim 8, wherein the digital signal processor is further configured to:

determine another data signal from the interference suppressed digital receiver signal;

subtract the another data signal from one of the interference suppressed digital receiver signal and the first digital receiver signal to generate another intermediate digital signal;

filter the another intermediate digital signal using another filter (620) having the frequency and bandwidth equal to the frequency offset and bandwidth, respectively, of the interference signal to generate another estimated interference signal; and

subtracting the another estimated interference signal from one of the interference suppressed digital receiver signal and the first digital receiver signal to generate another interference suppressed digital receiver signal.

11. The optical receiver of claim 8, wherein the noise optical signal constitutes a reflection of another optical signal transmitted by a transmitter other than the one transmitting the modulated optical signal, the reflection occurring over a bi-directional optical link over which both the another optical signal and the modulated optical signal are communicated.

12. The optical receiver of claim 8, wherein the frequency offset of the interference signal is less than a bandwidth of the modulated optical signal.

13. The optical receiver of claim 8, wherein the filter is a band-pass filter (520), and wherein the band-pass filter includes at least two cosine function multipliers and at least two sine function multipliers for multiplying the intermediate digital signal.

14. The optical receiver of claim 8, wherein the digital signal processor is configured to determine the frequency offset of the interference signal from the intermediate digital signal based on a result of a fast-Fourier-transform of the intermediate signal.

15. An optical transmitter (108, 802) comprising:
a laser (806) configured to generate an optical signal having a carrier frequency;
a modulator (808) for modulating the carrier frequency with a data signal to generate a modulated optical signal;
a laser tuner configured to tune the carrier frequency of the laser; and
a processor (810) configured to:
receive a frequency offset of an interference signal from a receiver, the frequency offset of the interference signal indicative of the difference between an optical signal received at the receiver and a noise optical signal, wherein the noise optical signal includes a reflected optical signal;
in response to receiving the frequency offset, dynamically compare the frequency offset with a bandwidth of the modulated optical signal; and
based on the frequency offset being less than the bandwidth, control the laser tuner to tune the carrier frequency of the laser such that the received frequency offset is greater than the bandwidth.

16. The optical transmitter of claim 15, wherein the laser tuner is a thermos-electric cooler configured to adjust the temperature of the laser in response to a control signal received from the second processor.

17. The optical transmitter of claim 15, wherein the noise optical signal constitutes a reflection of the modulated optical signal.

18. The optical receiver of claim 1 or claim 8, wherein the digital signal processor is configured to determine the bandwidth of the interference signal.