A Multilevel Modulation Scheme for High-Speed Wireless Infrared Communications

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Motivation

- A high data rate, short distance link is required to connect portable devices to:
  - backbone network, data storage, user interface peripherals, other portable devices ...

- Possible Solutions:
  - Mechanical connection
  - RF wireless link
  - Optical wireless link
Why Wireless Infrared?

- Advantages of Wireless IR links:
  - high data rate
  - unregulated bandwidth
  - lower cost
  - flexible interface
  - small form factor

- Constraint:
  - need to use inexpensive optical devices
LED emits incoherent light over a wide spectrum.

Photodiode is linear over a wide input range.
Experimental Link
**Experimental Results**

- **Results**
  - Bandwidth: 35 MHz
  - SFDR: 20 dB
Channel Constraints

◆ Physical channel constraints:
  • signals must remain non-negative
  • average output signal fixed for eye safety

◆ Practical channel limitations:
  • bandwidth of channel is limited
    – need bandwidth efficient modulation schemes for higher data rate transmission.
Conventional Optical Modulation Techniques

- Schemes based on pulse transmission
  - on-off keying
  - pulse position modulation (PPM)

- Well suited to optical fibre applications.
Pulse Amplitude Modulation (PAM)

- In each symbol interval, pulse assumes one of \( L \) non-negative levels.
  - non-negativity guaranteed.
  - average optical power set by symbol distribution.

![Diagram showing pulse amplitude modulation](image)
Quadrature PAM (QAM)

- Two $L$-PAM signals on quadrature carriers
  - fixed DC bias added to each symbol to ensure non-negative output
  - average optical power independent of data
Adaptively-Biased QAM (AB-QAM)

- $L^2$-QAM with square wave carriers
  - adaptive DC bias is added to each symbol to satisfy non-negativity constraint
  - average optical power set by data distribution
Example: 9-AB-QAM

**Constellation**

**Time-Domain**

- DC-bias
- In-phase
- Quadrature

- Points: (0.75, -0.75, 1.5), (0, 0.75, 0.75), (0.75, -0.75)

- Time: 0, Ts, 2Ts
AB-QAM Key Points

- Achieves an asymptotic 3dB optical SNR improvement over PAM by:
  - minimizing the amount of bias to optical signal
  - using information in symbol average:
    - SIGNAL SPACE DIVERSITY
Simulation Results

For \( L^2 = 49 \), BW fixed

Optical SNR (dB)

BER

- QAM
- PAM
- AB-QAM

Values:
- \( 10^{-20} \)
- \( 10^{-15} \)
- \( 10^{-10} \)
- \( 10^{-5} \)
- \( 10^{0} \)

Optical SNR (dB)
Conclusions

- Multilevel modulation schemes are necessary for next generation, short distance, high-speed wireless infrared links.

- AB-QAM provides a 3dB optical SNR gain over PAM, while maintaining the same bandwidth efficiency.