Creativity in Electrical and Electronic Engineering:

My Inspirations from the Physical World

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Summary

• Hypothesis: Inspiration comes from many places
  – Semiconductor laser models: a guitar and a 100-W stack (and a bucket of water)
  – VPIphotonics.com (my first company) and frustrating guitar stomp boxes
  – Cool Jazz and Orthogonal Division Multiplexing
  – Enhancing optical communications by analysing garage bands
  – Bionic vision & steam engines: both are boiler-making and energy inefficient (Monash Vision Group)

• Conclusion

• Questions and Discussion
1) The modes in a Fabry-Perot Laser mimic the vibrational modes of a guitar string

2) The gain within a laser cavity keeps the vibrations going. The E-bow kept guitar notes going by adding local gain.

So: Add an e-bow to get a laser model


The E-bow has a pick up to monitor the string, and amplifier, and a transducer to stimulate the string
Laser is divided into sections: samples of the optical field pass between them on “transmission lines”. Very *numerically efficient*

- Reflections create a resonant cavity supporting only certain modes
- (Frequency Selective) **Gain** amplifies some modes more than others
- The output powers of the amplifiers are limited by the *injected current*

One of my teenage hobbies was to make guitar effects boxes for a session musician. These could be strung together in many different ways to get interesting sounds.
OPALS allowed models of photonic components to be strung together

Monash Electro-Photonics Laboratory

the first Photonic ‘systems’ simulator

- Detailed laser models in the time domain
- Bidirectional interfaces communicate every picosecond
- easy Graphical User Interface (based on LabVIEW)
- First released February 1996
- Sold to Fujitsu as first customer (IBM second)

VPIphotonics’ customers in 2000

Monash Electro-Photonics Laboratory
Cool Jazz and OFDM

- Play slow music in large buildings
- The complexity is in the chords
  - The complexity carries the Information

A. J. Lowery and Liang B. Du, "Optical orthogonal division multiplexing for long haul optical communications: A review of the last five years" An invited review article for Optical Fiber Technology special edition "100G and Beyond (Ed. M. Chbat)", 17, 421-438 (2011)
Conventional systems transmit on a single frequency, using a ‘beat’ for a ‘1’ and a space for a ‘0’. Dispersion causes their energy to spread into adjacent beats:

 Optical OFDM transmits many parallel frequencies (‘notes’) simultaneously (a musical ‘chord’), held for a longer time. The information is in the complexity of the ‘chord’. Dispersion can be handled by Guard bands or Cyclic Prefixes. This method is extremely robust to dispersion impairments over long transmission distances.
OFDM

At the Transmitter
(multiple subcarriers shown in each symbol)

At the Receiver….

Fourier Transform window
Enhancing OFDM with clipping

- ACO-OFDM – asymmetrically clipped optical orthogonal frequency division multiplexing
- Reduces DC content – less optical power
- BUT: only uses half of the subcarriers (odds) because of harmonic distortion falling on the even subcarriers

Enhancing OFDM & Garage Bands

A poor band – one amplifier (well, they had a car!):

All instruments through one amplifier:
This gives serious and unpleasant intermodulation distortion when amplifier clips, even if they are playing the same chords (but at octaves).

http://home.unet.nl/kesteloo/vipers.html
A richer band:

Separate amplifiers for each instrument:

The clipping within each amplifier only causes pleasant distortion.

The sound is combined in the air.

Enhancing OFDM with separate clipping for each chord

This trick* can be used to enhance the spectral efficiency of optical OFDM signals.

*clipping the instruments separately, then adding the results

Successive interference cancelation at the receiver reveals the chords. The error vector magnitude (EVM) is less than any other (unlayered) modulation format, for the same optical power.

All results with equal:
- Equal optical power
- Equal SNR (25 dB)
- Numbers of subcarriers (56)
Enhancing OFDM & Garage Bands

Enhanced/Layered ACO-OFDM outperforms other methods (i.e., needs the lowest optical power for a given spectral efficiency) at spectral efficiencies above 3 bit/s/Hz.
Implementing OFDM All-Optically (Optical Fourier transforms)


The AWGR as an Inverse FT (with a Cyclic Prefix)

OFDM Photonic Integrated Circuit: Monash I

IMEC OFDM Tx chip in Silicon-on-insulator (SOI) with modulators and AWGR-based IFT
Conclusions

• Many of my ideas have come from:
  – Musical instruments
  – Sound
  – Analog electronics/ effects boxes
  – Railway track layouts (photonic circuits)

• I then usually simulate the ideas using software

• I have needed mathematics to create models to optimise and communicate these ideas, and physics to ensure that they are grounded

• “Engineering-Inspired-Engineering”

• Questions and Discussion