Differential Pulse Position Modulation for 5 GHz

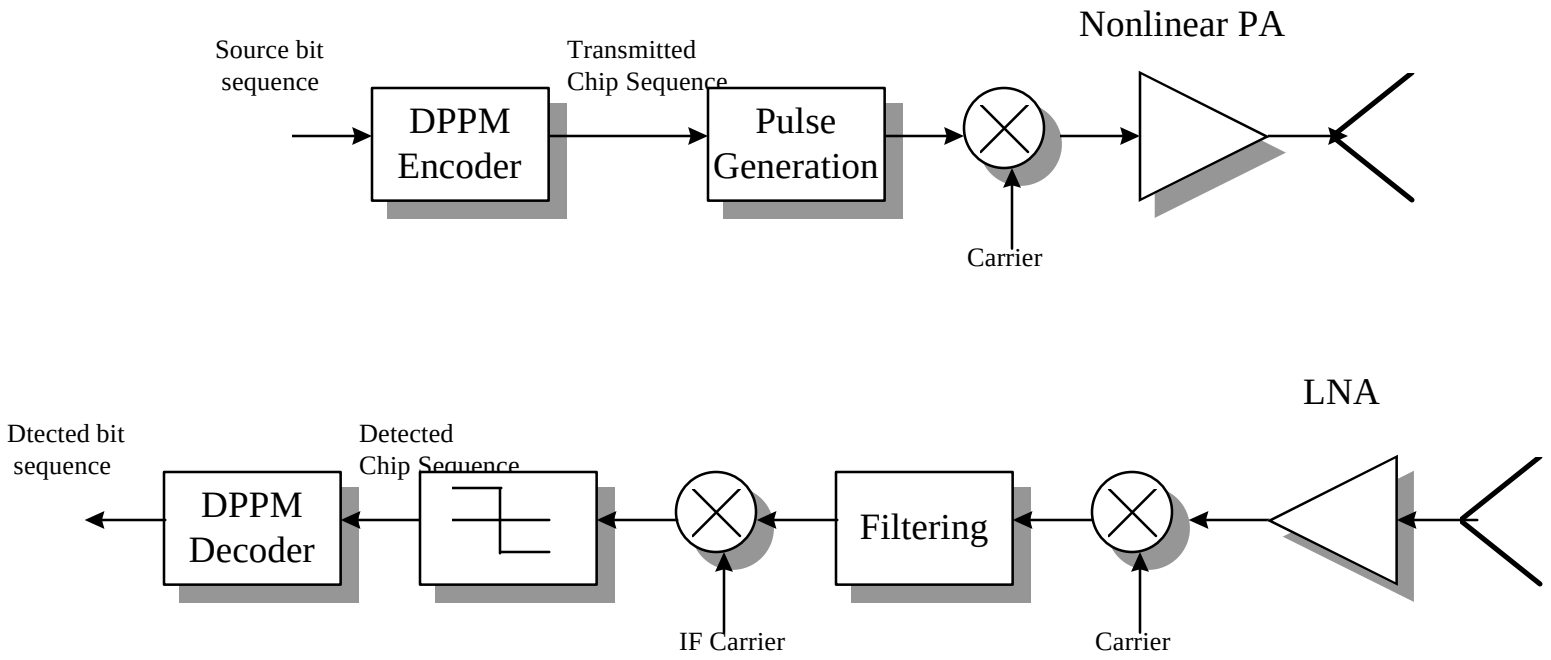
Why DPPM?

- Low-Cost, Low-Complexity 5 GHz PHY
  - Non-Coherent Detection
  - No Equalizer
    - Equalizer Training & Error Propagation are fundamental problems.
    - "Text-Book" Equalizers and their Simulations don't make Products.
  - No FFT Processor
    - OFDM more suitable for outdoors.
    - Sub-optimal for indoors.
- Power Efficient
  - Transmit with Nonlinear PA & Pulsed.
  - Receive with low-current Baseband Processor.
- User Throughput Efficient
- U-NII Compliant
  - 10 Mbps products at 5.2, 5.3, & 5.775 NOW
- Demonstrated Implementations evidence at 10 Mbps.
- 5 GHz technology available for licensing.

Introduction to DPPM

- Unexplored Potential for RF Applications
  - "Differential Pulse-Position Modulation for Power-Efficient Optical Communcaitons", D. Shiu & J. Kahn, University of California, Berkeley, Submitted to IEEE Transactions on Communications, August 1997.
  - "Differential Overlapping Pulse-Position Modulation in Optical Direct-Detection Channel", T. Ohtsuki et al., IEEETransactions on Communications, December 1994.
  - "Capacity and Cutoff Rate for Optical Overlapping Pulse-Position Modulation Channels", H. Shalaby et al., IEEETransactions on Communications, 1994.
  - Very popular for high-speed optical communications (AWGN & Multipath Channels)
  - (fiber optics, sattelite communications, IR WLANs)
- Very Low RF Power Communications Candidate,
  - (FCC 15.249: "Low-Power Devices", RadioLAN Product)
- DPPM has higher capacity and cutoff rate than PPM
- DPPM with overlapping pulses: Ideal for Power-Limited & Bandwidth-Limited Applications
- DPPM is a simple nonlinear block code
  - L-binary L-tuples with unity hamming weight.

DPPM Transceiver



Power Efficient Transmission

- Nonlinear Amplifier
- Pulsed PA
- TX Current Competitive Analysis
  - Class of MMIC / Power Device
  - Cost
  - Complexity
    - Thermal
    - RF
    - Mechanical / Size
- Transmit Power Competitive Analysis
  - Present U-NII Regulations
  - After Re-Consideration

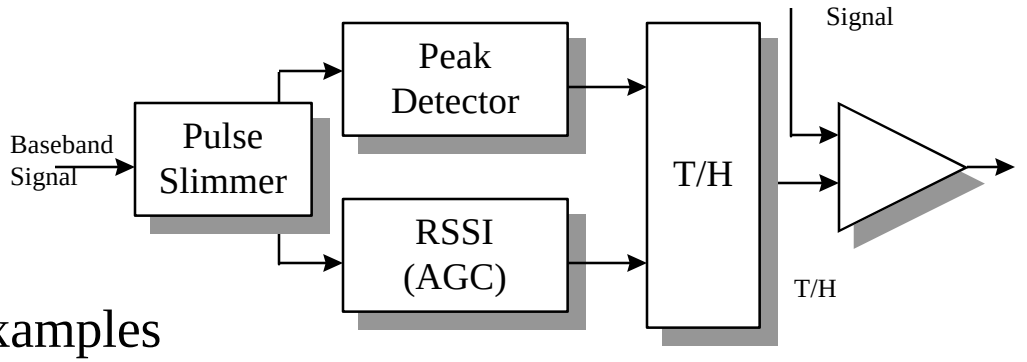
Proposer	Back-Off	TX Current (For transmitting +17 dBm) 100% Duty cycle LB	TX Current (For transmitting +17 dBm) w. Pulse Duty cycle LB
RadioLAN	0.5	150 mA	50
NEC / Br	5.5	600 mA	600 mA
Lucent / NTT	5.2	600 mA	600 mA

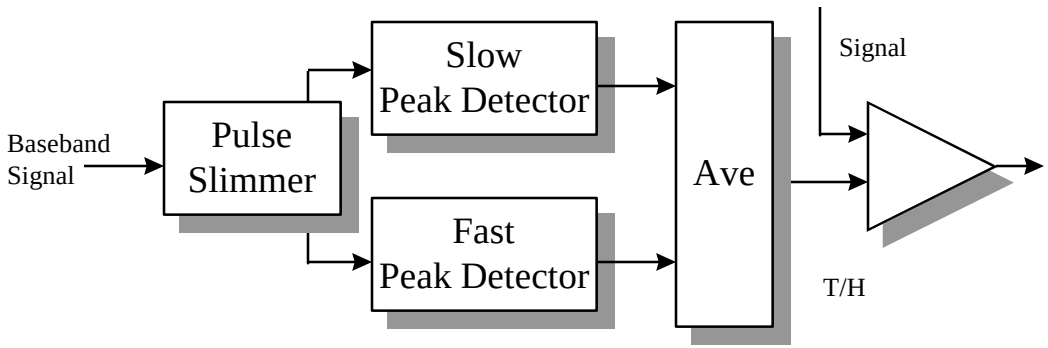
Proposer	Back-Off	TX Current (For transmitting +24 dBm) 100% Duty cycle MB	TX Current (For transmitting +24 dBm) w. Pulse Duty cycle MB
RadioLAN	0.5	600 mA	220
NEC / Br	7.5	3300 mA	3300 mA
Lucent / NTT	8.2	3600 mA	3600 mA

Proposer	Back-Off	TX Power Out (For Fixed + 17 dBm PA) LB
RadioLAN	0.5	+17
NEC / Br	5.5	+11.5
Lucent / NTT	5.2	+11.8

Multipath Tolerance

- Inter-Symbol
  - Embedded Guard-Time:
    - 100 nsec Guard-Time is one of the “Pulse Positions”
  - Pulse Processing
- Intra-Symbol
  - Blanking
    - Blankingpost-rising-edge distortions
  - Edge-Detection
- Simple Detector Implementations Examples





Power Efficient Reciever

- RF Receiver DC Power
  - Lower Current due to Non-Coherent RF/IF Receivers
- Basband Processor DC Power
- Receive Baseband Current Competitive Analysis

Proposer	RX Current Basband Processor
RadioLAN	25 mA
NEC / Br	120 mA
Lucent / NTT	40 mA

- Receive Baseband Complexity Competitive Analysis

Proposer	Basband Processor Complexity
RadioLAN	2K Transistors
NEC / Br	100-200 KGates
Lucent / NTT	158 K Gates

Throughput Efficiency

- Single-Channel, Single Rate Efficiency
- Aggregate Rate per AP, Single Rate, Indoor per Channel
  - User Rate
- Aggregate Rate per AP, Multi Rate, Indoor per Channel
- Aggregate Rate per AP, Single Rate, Free Space per Channel
- Aggregate Rate per AP, Multi Rate, Free Space per Channel

Proposal and Rate	Aggregate rate per AP single rate Free-Space	Aggregate rate per AP, multirate Free-Space	Aggregate rate per AP single rate Indoor	Aggregate rate per AP, multirate Indoor	Efficiency ACK at same rate	Efficiency ACK at basic rate
RadioLAN 20 Mb	6.49	11.75	7.37	11.75	0.881	0.872
NEC / Br 21 Mb	5.76	10.6	5.76	10.6	0.795	0.795
Lucent / NTT 20 Mb	3.05	7.46	7.59	11.48	0.802	0.802

DPPM Summary

- Low-Cost, Low-Complexity 5 GHz PHY
  - Non-Coherent
  - No Equalizer (Equalizer Training & Error Propagation are fundamental problems)
  - No FFT Processor
- Power Efficient
  - Transmit
  - Receive
- User Throughput Efficient
  - 10 Mbps Fall-back rate!
  - higher data rates are possible
- U-NII Compliant
  - FCC-Approved 10 Mbps, U-NII products at 5.2, 5.3, & 5.775 NOW
- Demonstrated Implementations evidence at 10 Mbps.
- 5 GHz Chip-set and technology available for licensing.

DPPM

- Simple
- Fast
- Low-Cost

A Proven Path to Product

Complexity & Cost