Why Should you Choose Offset Quadrature Modulation?

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Why not PPM?

- PPM does not live to its promises:
  - Power saving by PA switching is unrealistic (with stringent out-of-band restrictions)
  - Sensitivity to multipath (how to set threshold?)
- PPM proposal did not show complete data
- PPM data contains inconsistencies
  - Unrealistic AWGN sensitivities

OQM vs. OFDM - Similarities

- Both proposals are basically good
  - Both utilize multipath as a frequency diversity, OFDM by coding, OQM by equalization
- Both proposals behave similarly in terms of
  - Sensitivity
  - Throughput
  - Phase noise tolerance
  - CCI

OQM advantages vs. OFDM

- OQM enables **smaller backoffs** (especially in binary mode)
- Higher rates reached
- Possibility to trade multipath tolerance for complexity

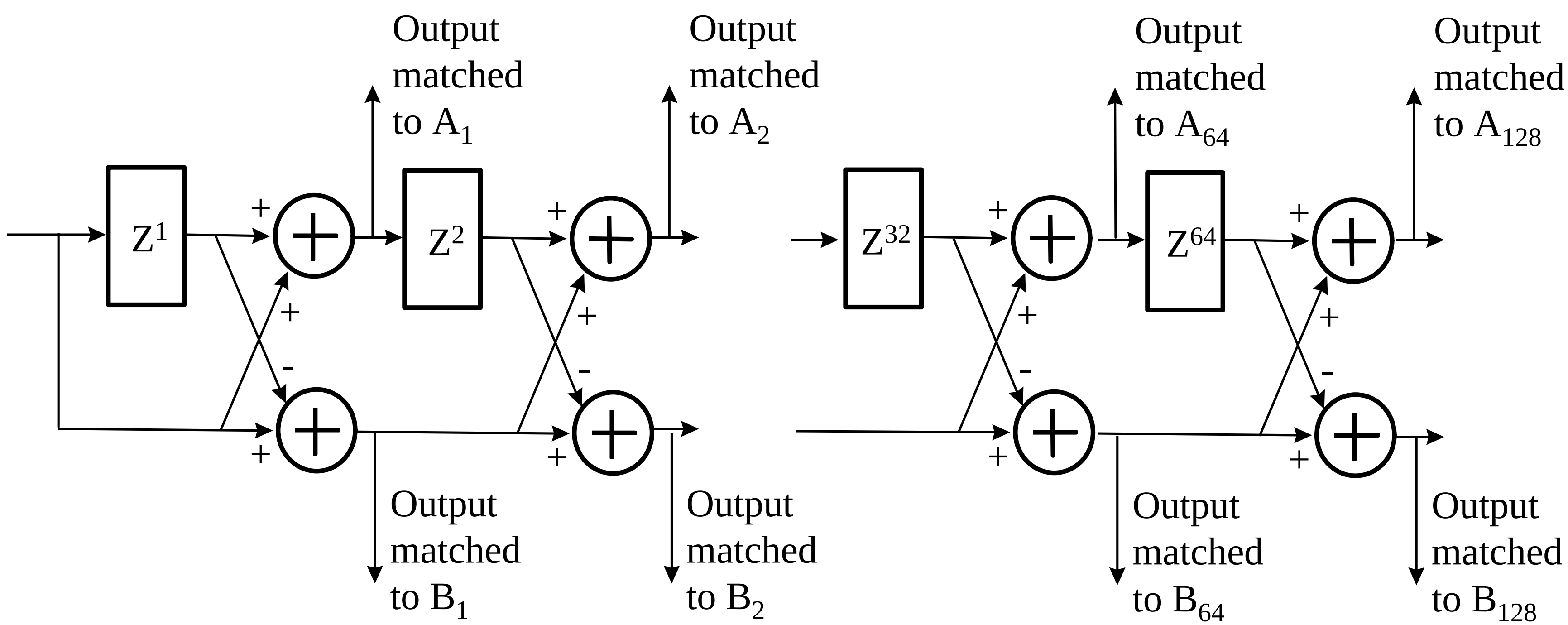
OQM disadvantages vs. OFDM

- More processing power is required
- Less channels (9 vs. 11)
- Harder to implement low, more robust rates

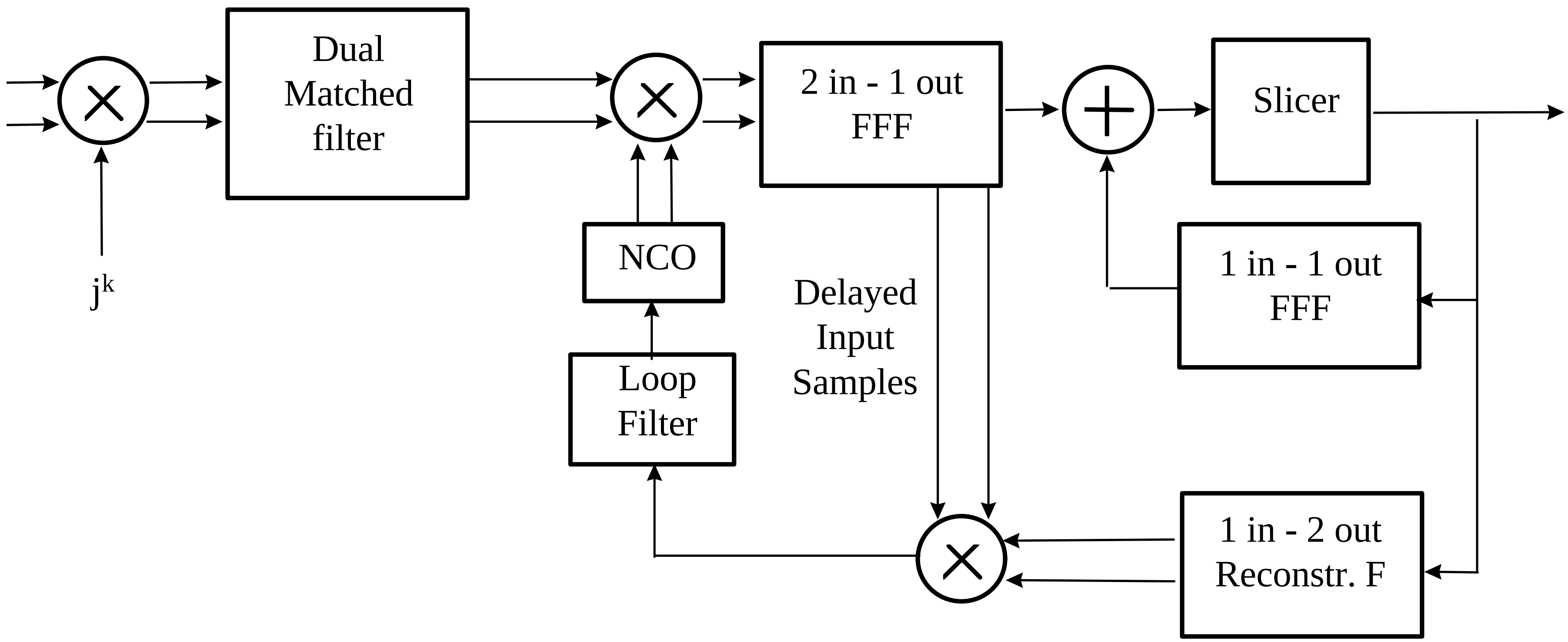
OQM is practical - some details

- Simple CCA implementation
- Equalization
- Equalizer initialization
- Carrier Tracking

Header and CCA detection



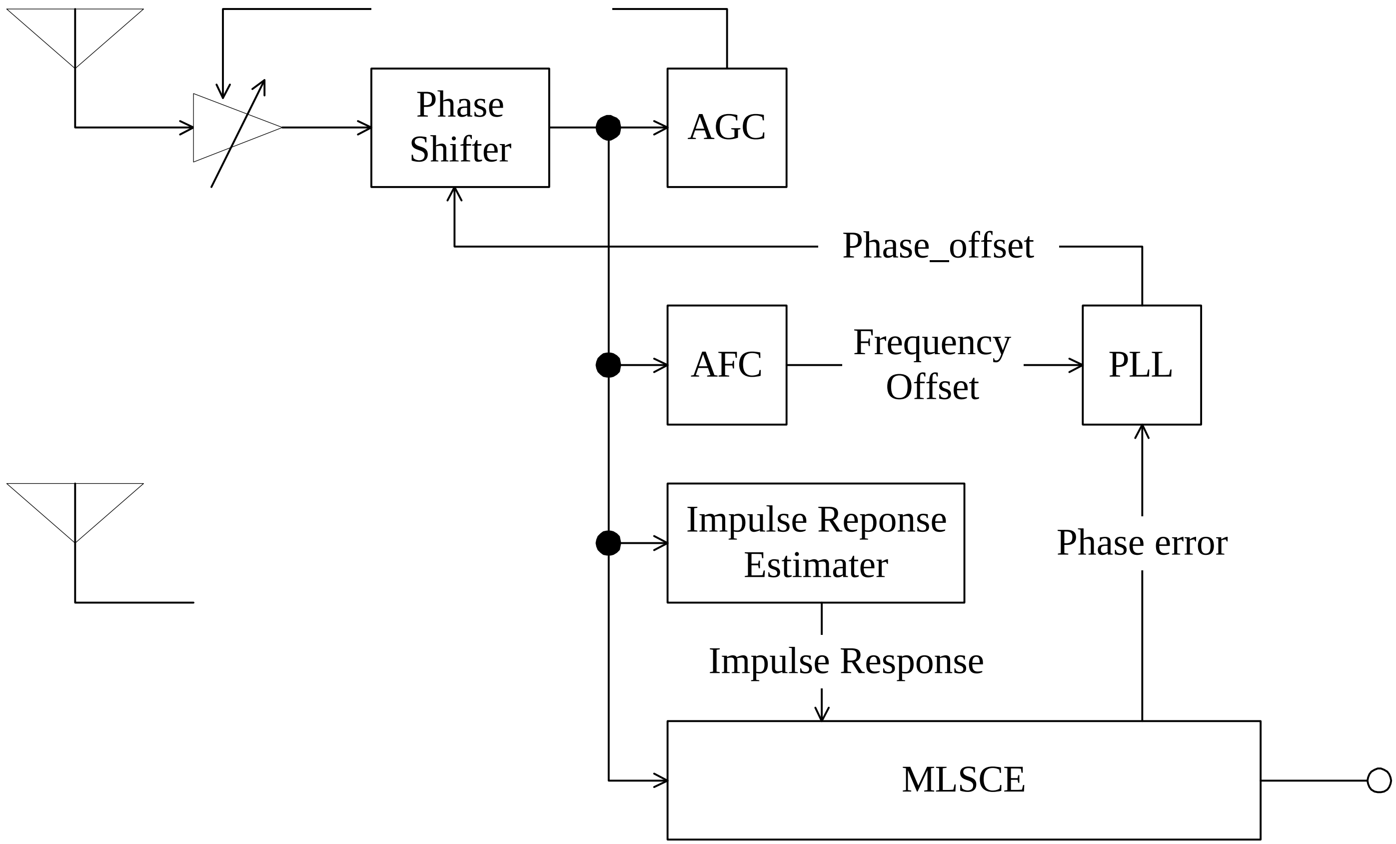
Equalizer and Carrier tracking



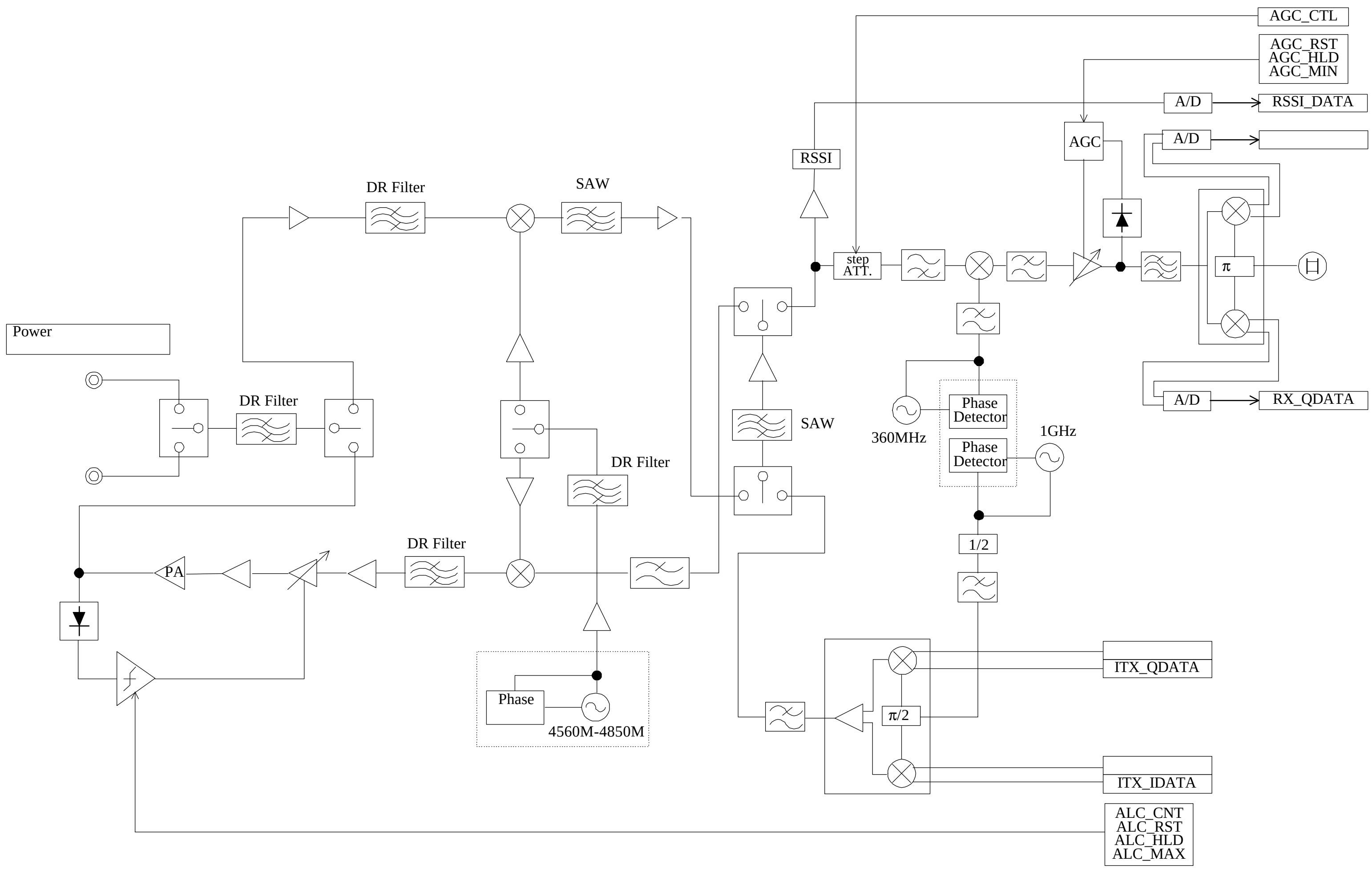
Equalizer Initialization

- Paper by Dan Raphaeli - 98/188
  - Based on Iterative (Gauss-Siedel) technique for matrix inversion
  - Adapted to high speed implementation (no divisions, just shifts
  - Fits well within framework of hardware already present for equalization

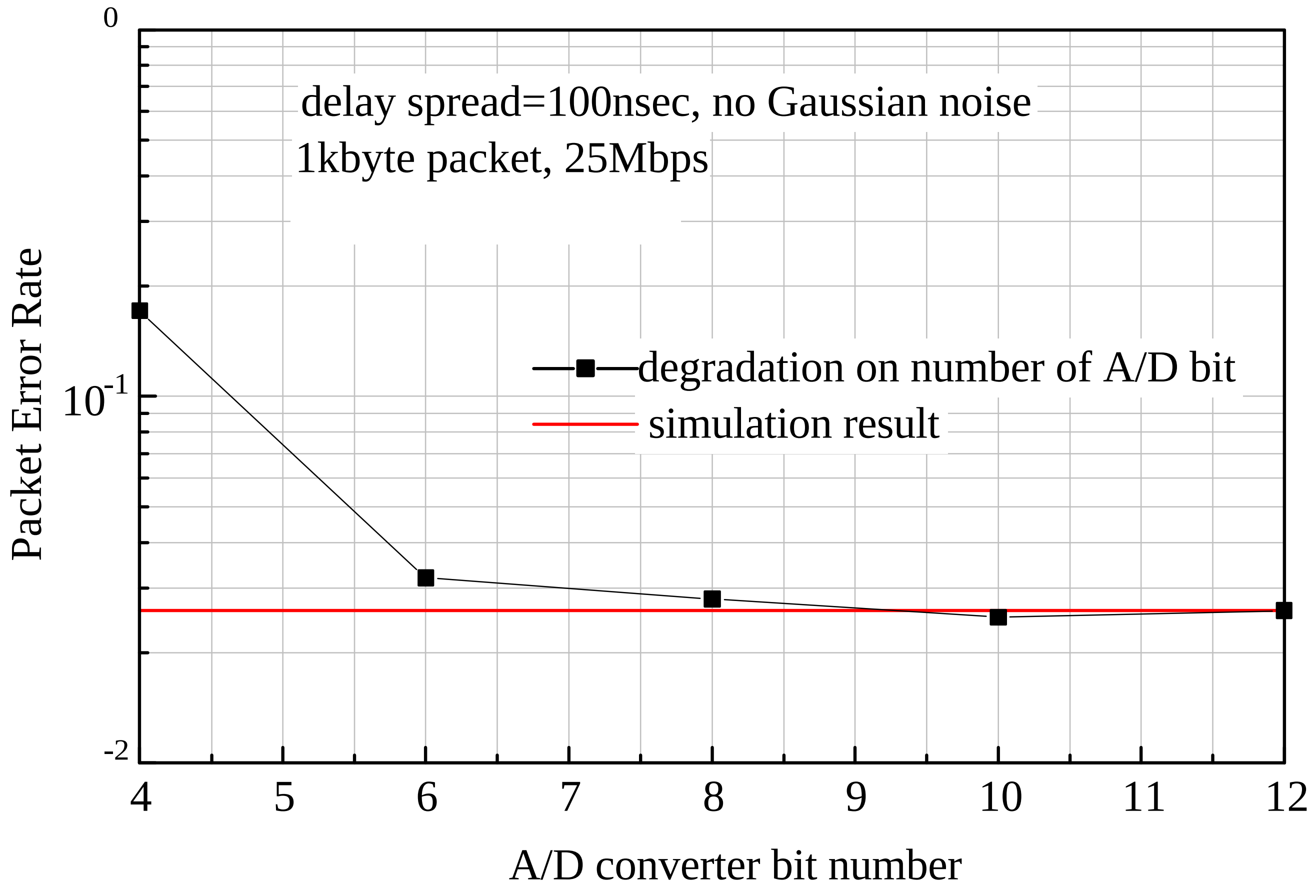
RX block diagram



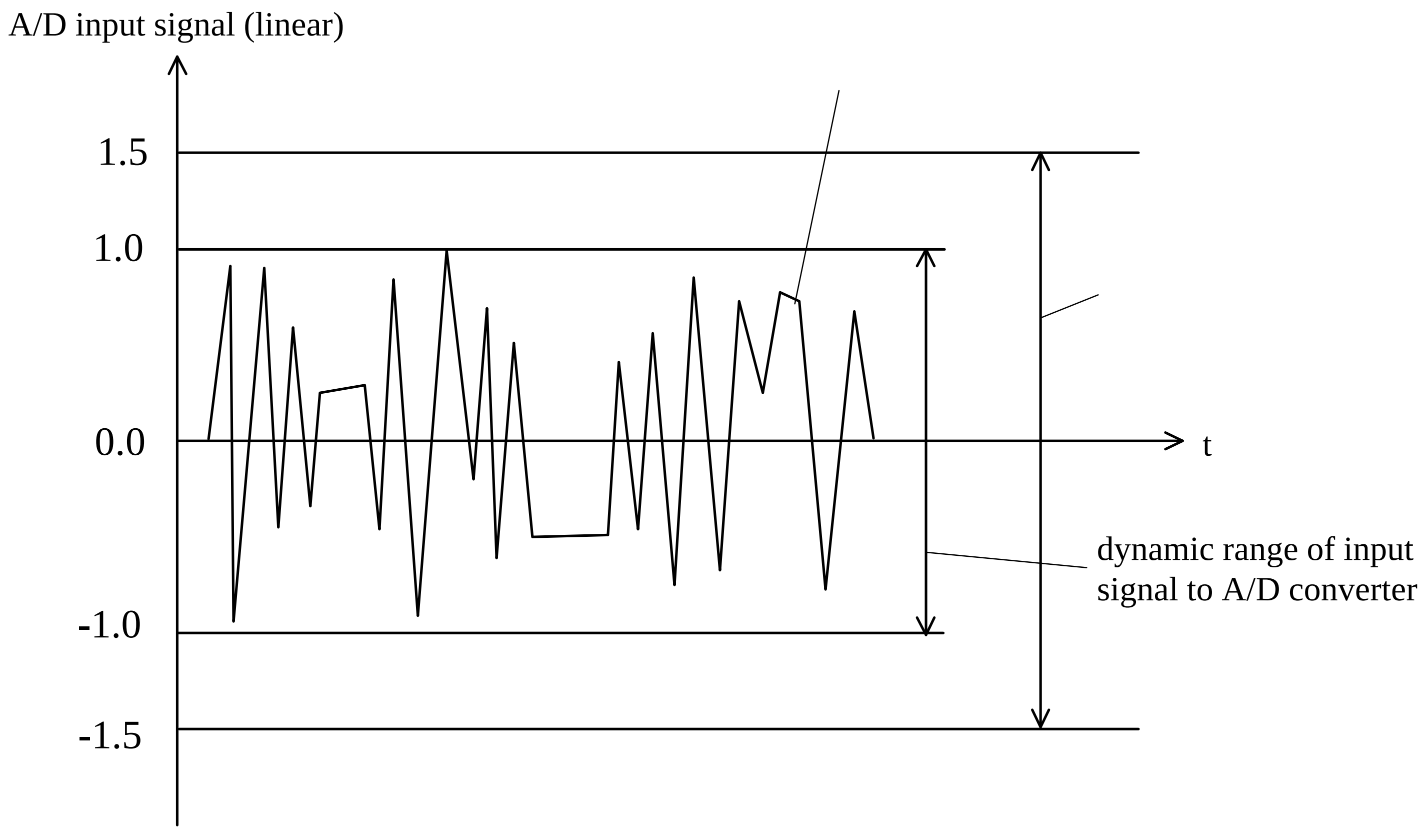
RF/IF chain for O-QPSK



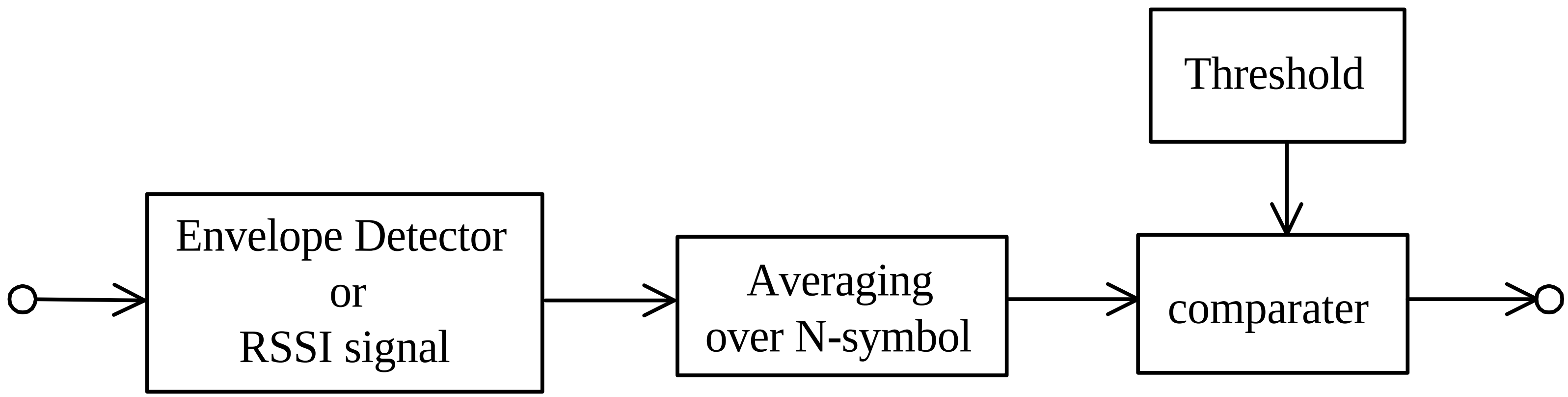
A/D accuracy (1)



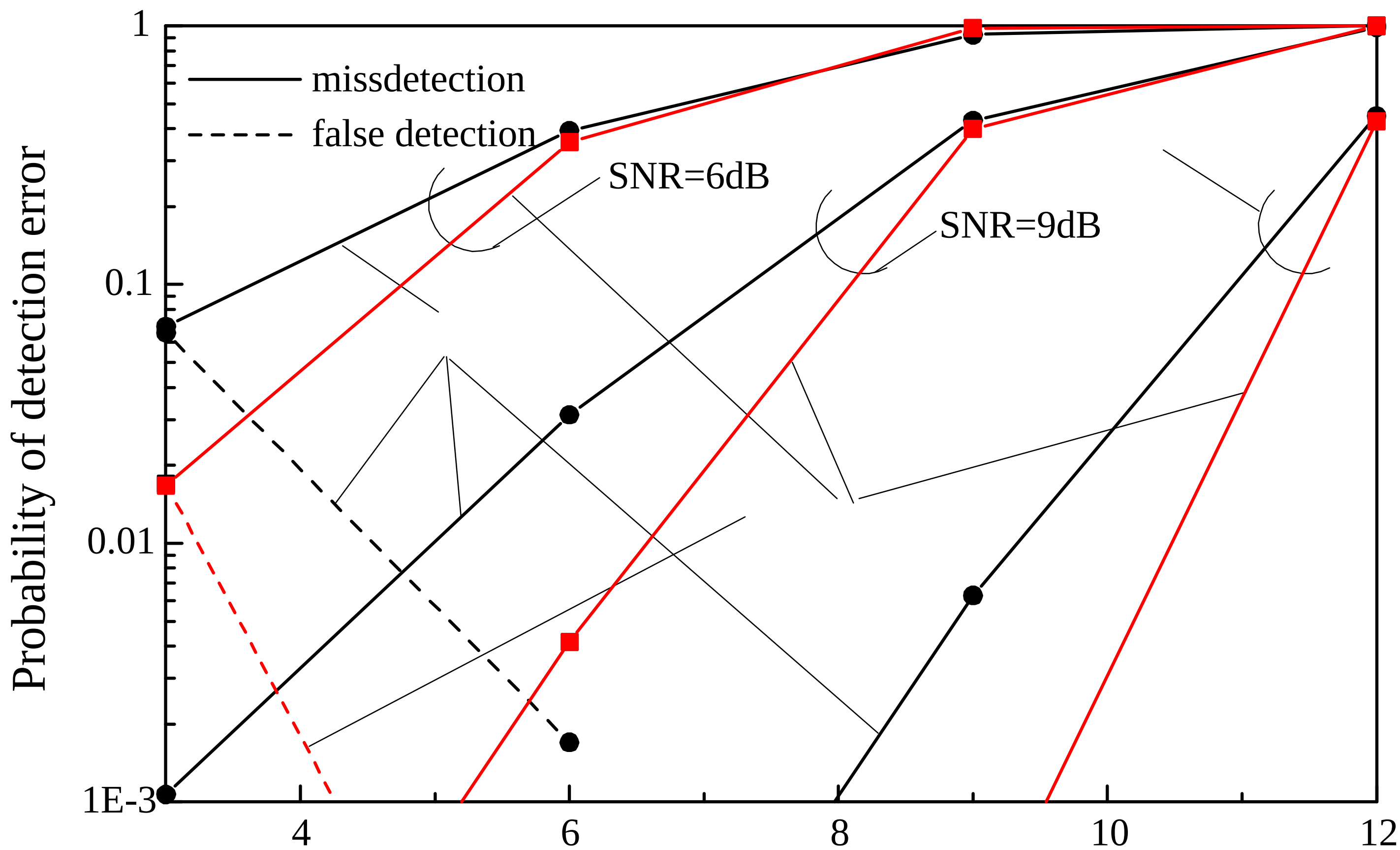
AD accuracy (2)



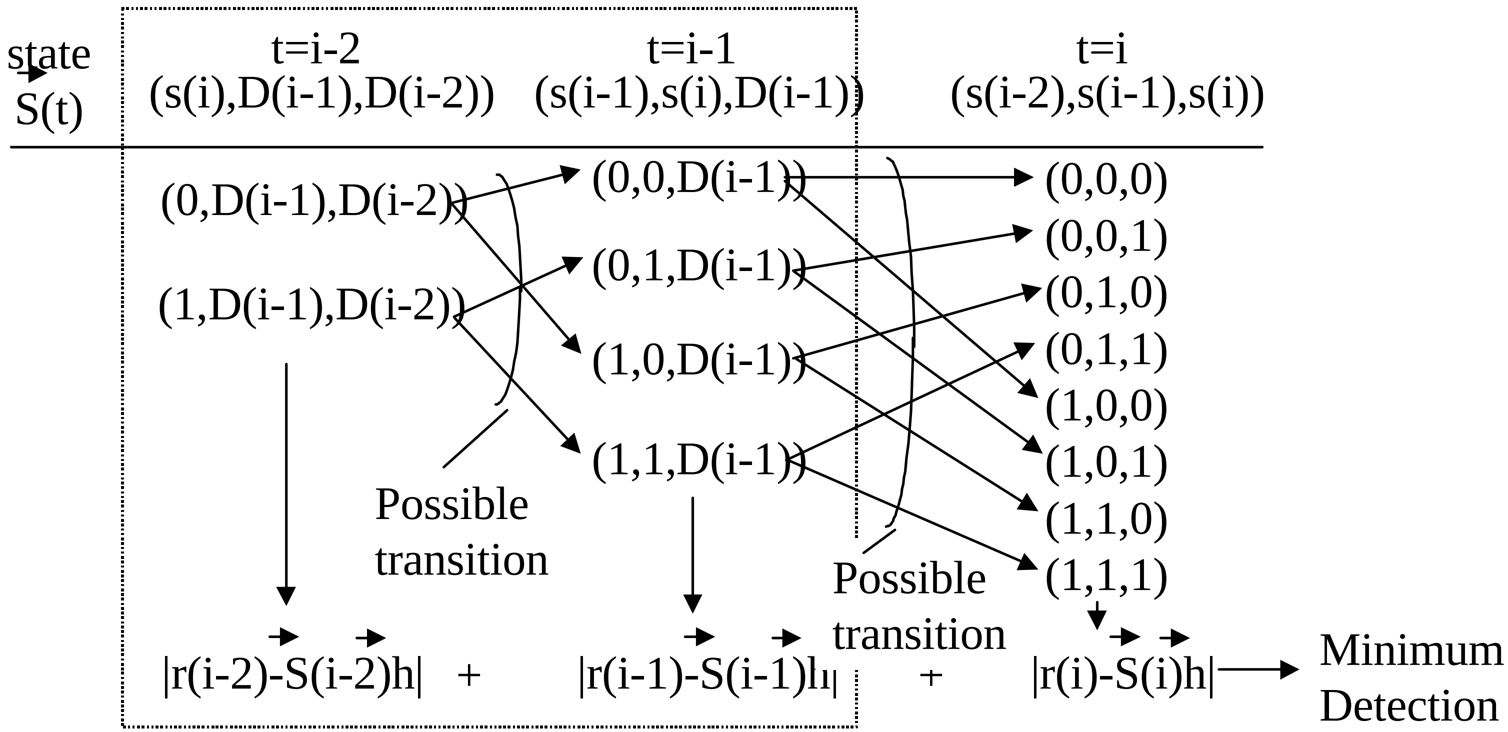
CCA mechanism (1)



CCA mechanism (2)

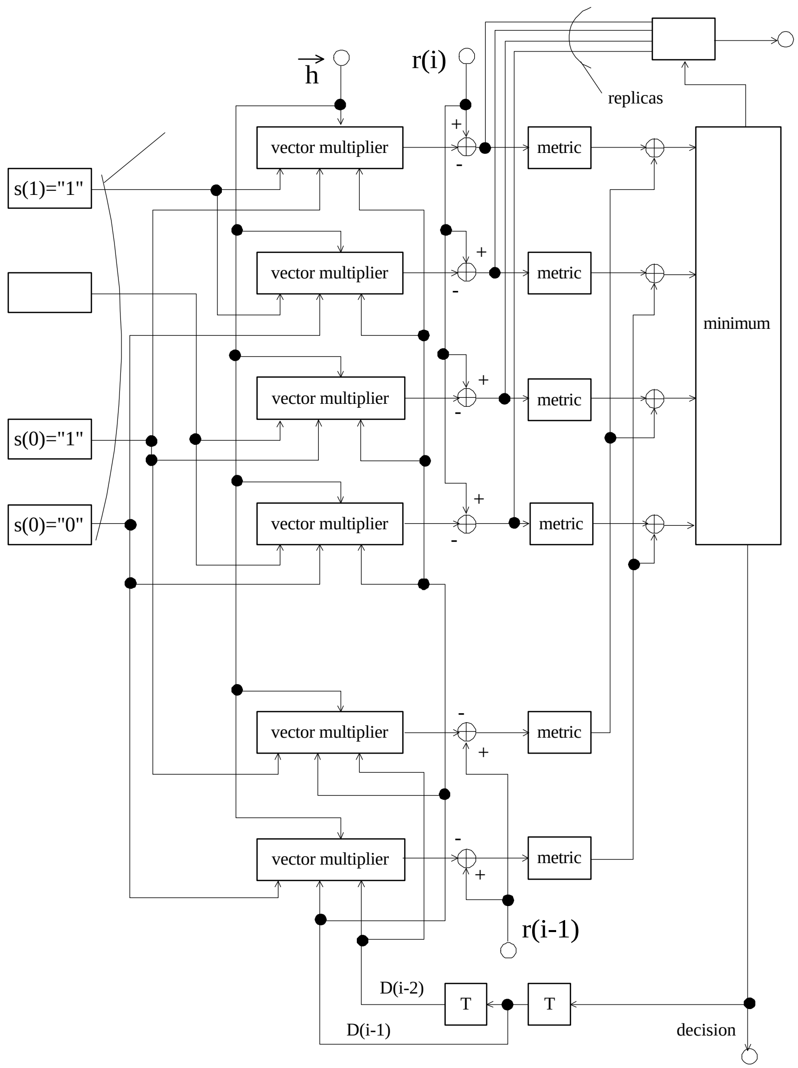


Equalizer Architecture

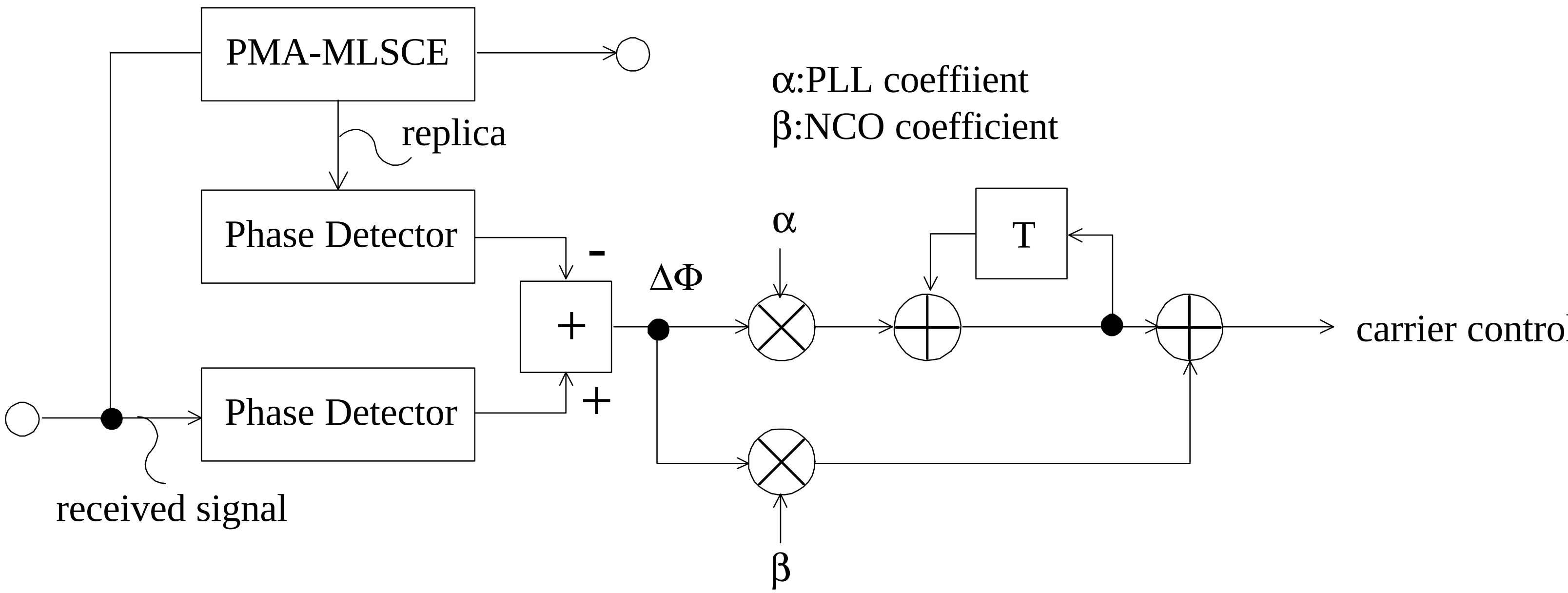


s(i): symbol candidate D(i-k): Decision result at t=i-k r(i): received signal at t=i

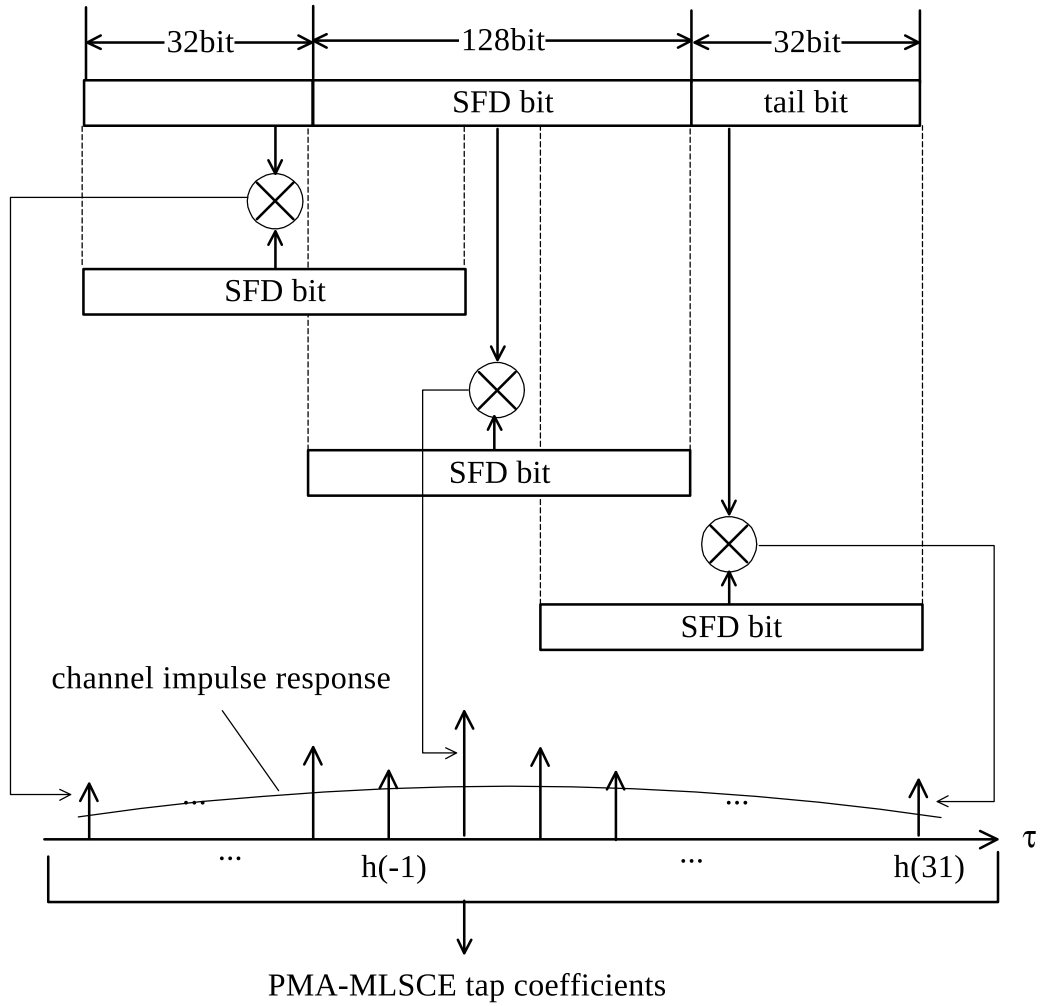
Equalizer Architecture



PLL Architecture



Equalizer Initialization



Sensitivity @ Delay Spread

Proposal and Rate	Pr [dBm] at PER=10%, AWGN, 64b	Pr [dBm] at PER=10%, AWGN, 1000b	Trms at PER=10%, noise free, 64b	Trms at PER=10%, noise free, 1000b	Pr [dBm] @ 20%, with Trms @ 10%, 64b	Pr [dBm] @ 20%, with Trms @ 10%, 1000b
LT+NTT 5 Mb	-90.6 dBm	-89.6 dBm	> 500 ns	> 500 ns	-86.1 dBm*1	-83.1 dBm*1
LT+NTT 10 Mb	-87.5 dBm	-86.3 dBm	> 500 ns	460 ns	-78.2 dBm	-74.1 dBm
LT+NTT 15 Mb	-84.6 dBm	-83.5 dBm	320 ns	240 ns	-71.6 dBm	-68.5 dBm
LT+NTT 20 Mb	-83.0 dBm	-81.0 dBm	300 ns	225 ns	-75.0 dBm	-71.0 dBm
LT+NTT 30 Mb	-79.2 dBm	-77.2 dBm	175 ns	150 ns	-69.2 dBm	-66.2 dBm
Br+NEC 21 Mb	-83.5 dBm	-82.5 dBm	182 nsec (Br) 175 nsec (N8) 120 nsec (N4)	174 nsec (Br) 175 nsec (N8) 120 nsec (N4)	-72 dBm	-71 dBm
Br+NEC 25 Mb	-81.5 dBm	-80 dBm	167 nsec (Br) 175 nsec (N8) 120 nsec (N4)	164 nsec (Br) 175 nsec (N8) 120 nsec (N4)	-72 dBm	-71 dBm
Br+NEC 42 Mb	-76 dBm	-75.5 dBm	83 nsec	75 nsec	-66 dBm	-66 dBm
Br+NEC 50 Mb	-74 dBm	-73 dBm	77 nsec	73 nsec	-66 dBm	-65 dBm
RadioLAN 10 Mb	-88 dBm	-85 dBm	200 nsec	180 nsec	-72 dBm	-71 dBm
RadioLAN 20 Mb	-84 dBm	-81 dBm	150 nsec	140 nsec	-69 dBm	-68 dBm
RadioLAN 20+RS	-83 dBm	-80.5 dBm	140 nsec	130 nsec	-68 dBm	-68 dBm

Backoff requirements

Proposal and Rate	Backoff [dB] @LB Pmax (LB U-NII regulations)	Backoff [dB] @MB Pmax (MB U-NII regulations)	Backoff [dB] @LB Pmax (restricted regulations)	Backoff [dB] @MB Pmax (restricted regulations)	Backoff [dB] @Psat=250 mW, (restricted regulations)
LT+NTT 5 Mb	5 dB	5 dB	5.2 dB	8.2 dB	6.3 dB
LT+NTT 10 Mb	5 dB	5 dB	5.2 dB	8.2 dB	6.3 dB
LT+NTT 15 Mb	5 dB	5 dB	5.2 dB	8.2 dB	6.3 dB
LT+NTT 20 Mb	5 dB	5 dB	5.2 dB	8.2 dB	6.3 dB
LT+NTT 30 Mb	5 dB	5 dB	5.2 dB	8.2 dB	6.3 dB
Br+NEC 21 Mb	2 dB	2 dB	5.5 dB	7.5 dB	6 dB
Br+NEC 25 Mb	2 dB	2 dB	5.5 dB	7.5 dB	6 dB
Br+NEC 42 Mb	4 dB *1	4 dB *1	6.5 dB	8.5 dB	7 dB
Br+NEC 50 Mb	4 dB *1	4 dB *1	6.5 dB	8.5 dB	7 dB
RadioLAN 10 Mb	0	0	0	0	0
RadioLAN 20 Mb	0.5	0.5	0.5	0.5	0.5
RadioLAN 20+RS	0.5	0.5	0.5	0.5	0.5

Note: (by Br+NEC) The backoff at 42/50 Mb/s with U-NII regulations is dominated by performance degradation rather than by the regulatory restrictions.

AWGN Link Budget

Proposal and Rate	AWGN Sensitivity @NF=10 dB, no degr. [dBm]	Loss [dB] @LB Pmax	Loss [dB] @MB Pmax	Loss [dB] at @Psat=250 mW, (MB U-NII regulations)	Loss [dB] at @Psat=250 mW, (restricted regulations)
LT+NTT 5 Mb	-89.6 dBm	104.4 dB (30 mW)	111.4 dB (150 mW)	108.6 dB	107.3 dB
LT+NTT 10 Mb	-86.3 dBm	101.1 dB	108.1 dB	105.3 dB	104.0 dB
LT+NTT 15 Mb	-83.5 dBm	98.3 dB	105.3 dB	102.5 dB	101.2 dB
LT+NTT 20 Mb	-81.0 dBm	95.8 dB	102.8 dB	100.0 dB	98.7 dB
LT+NTT 30 Mb	-77.2 dBm	92.0 dB	99.0 dB	96.2 dB	94.9 dB
Br+NEC 21 Mb	-82.5 dBm	97 dB (30 mW)	104 dB (150 mW)	104 dB	100.5 dB
Br+NEC 25 Mb	-80 dBm	94.5 dB	101.5 dB	101.5 dB	98 dB
Br+NEC 42 Mb	-75.5 dBm	90 dB	97 dB	95.5 dB	92.5 dB
Br+NEC 50 Mb	-73 dBm	87.5 dB	94.5 dB	93 dB	90 dB
RadioLAN 10 Mb	-85 dBm	102 dB (50 mW)	109 dB (250 mW)	102 dB	109 dB
RadioLAN 20 Mb	-81 dBm	98 dB	105 dB	97.5 dB	104.5 dB
RadioLAN 20+RS	-80.5 dBm	97.5 dB	104.5 dB	97 dB	104 dB

Choose OQM!!!

- It is practical for low-2-medium delay spreads
- It optimizes a resource which will not improve with time
- You can match a complexity to an application