Submission to
IEEE P802.11
Wireless LANs

Harris/Lucent TGb
Compromise CCK (11Mbps) Proposal

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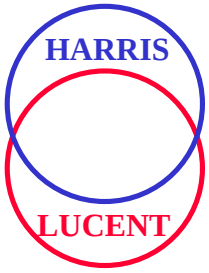
KEY FEATURES

- 11 and 5.5 Mbps data rates
- Outstanding high-multipath performance
- Outstanding low-SNR performance
- Seamless interoperability with existing DS and FH
- Clean, extensible receiver architectures enabled
- Maintains QPSK chips at 11 MHz chip rate
- Maintains 3 frequency channels
- FCC and MKK regulations satisfied

MERGER EASE



merge

HARRIS
- **Codeword change only**
- **Modified QMBOK**

LUCENT
- **Codeword change**
- **Do not position modulate**

COMPROMISE ADVANTAGES RELATIVE TO LUCENT'S MAY PROPOSAL

- 4 dB less PA Backoff.
- RAKE receiver foundation maintained.
- RAKE married to HARRIS's Equalizer simplifies design over BCPM TSE/MS.
- 11 Mbps 1K byte packet performance.
  - May: 130 nsec
  - July: 226 nsec at lower complexity

COMPROMISE ADVANTAGES RELATIVE TO HARRIS'S MAY PROPOSAL

		Chip Equalizer MAY	RAKE + ISI Eq. JULY	
MULTIPATH ROBUSTNESS • RMS delay spread • Bigger is better • 64 byte packet	5.5 Mbps:	226 nsec	450 nsec	200% Better
	11 Mbps:	186 nsec	330 nsec	
NOISE ROBUSTNESS • Eb/No dB • Smaller is better • With Equalizer • 1K byte packet		MAY	JULY	
	5.5 Mbps:	25.2 dB	17.7 dB	7-8 dB Better
	11 Mbps:	24.7 dB	17.7 dB	
ARCHITECTURE • Design ease • Gate count • Power draw		MAY	JULY	
	1, 2 Mbps:	RAKE	RAKE and Equalizer Integrated	Cleaner Design
	5.5, 11 Mbps:	FF/FB Equal		

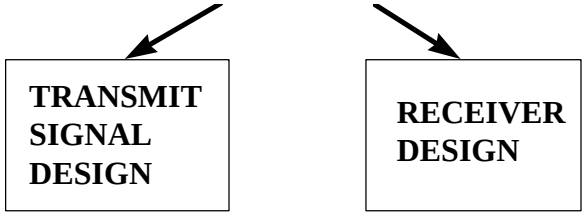
COMPROMISE OR NEW PROPOSAL?

CLEARLY A COMPROMISE BECAUSE

- BPSK or QPSK chips are used (Harris)
- 1-and-2 MBps DSSS-like signal (Lucent & Harris)
  - Phase-modulated codewords
- 11 Mcps rate maintained (Harris & Lucent)
  - Spectrum (bandwidth) unchanged
- Next Generation-QMBOK (Harris) codeword called CCK used
- Seamless interoperability maintained with DS and FH
- Merged architecture: RAKE (Lucent) with Equalizer (Harris)

PERFORMANCE: WAVEFORM Versus RECEIVER

PERFORMANCE ENABLERS



- Distance properties

- Wide choice range
- Does it fully exploit Tx signal features?

SIGNAL DESIGN

TESTPOINT
5.5 MBPS
8 CHIP CODEWORDS

SIMULATION ASSUMPTIONS
6 Finger RAKE RCVR
8 Samples/chip CIR Decimated To 1

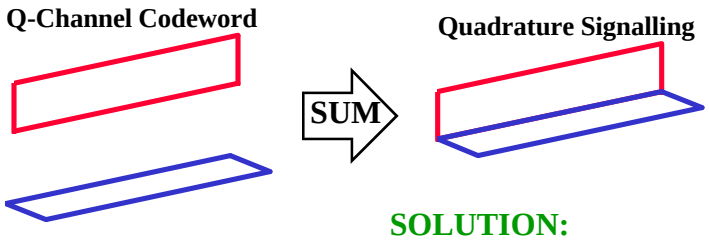
	MBOK CoverCode 03 h	MBOK CoverCode 12 h	CCK 4-ARY
DELAY SPREAD nsec	50	225	320

CODEWORD STUDY

- Jointly performed comprehensive codeword study
- Examined 8, 11 and 16 chip codes
- Examined WALSH and cover codes
- Examined real-chip (MBOK) versus complex-chip (CCK) codes
- Computed matched-filter-bound to examine fundamental distance properties in multipath
- Jointly-examined against receiver architectures
- CCK gave best overall performance and architecture

I/Q MULTIPATH CORRUPTION

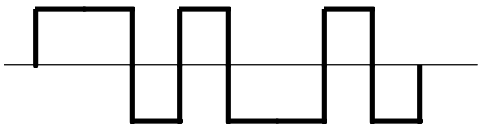
- **HARRIS'S Quadrature-MBOK**
- **LUCENT'S Quadrature-BCPM**
- **CORRUPTED BY MULTIPATH PHASE ROTATIONS**



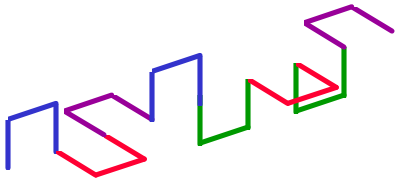
SOLUTION:
Serially-Encode QPSK chips

CODE DIMENSIONALITY

8 BPSK CHIPS: 2^8 = 256 Codewords



8 QPSK CHIPS: 4^8 = 65536 Codewords



COMPLEMENTARY CODES

8 Chip/4 Phase ϕ: 0, $\pi/2$, π, $3\pi/2$

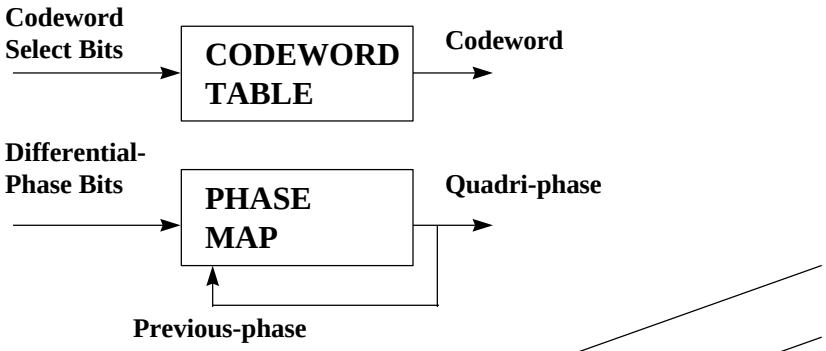
$$c = \{e^{j(\phi_1+\phi_2+\phi_3+\phi_4)}, e^{j(\phi_1+\phi_3+\phi_4)}, e^{j(\phi_1+\phi_2+\phi_4)},$$
$$-e^{j(\phi_1+\phi_4)}, e^{j(\phi_1+\phi_2+\phi_3)}, e^{j(\phi_1+\phi_3)}, -e^{j(\phi_1+\phi_2)}, e^{j\phi_1}\}$$

- Directly encodes complex (QPSK) chips
- ϕ1 quadriphase rotates whole codeword
- 64 codewords before quadriphase
- 256 codewords after quadriphase (8 bits)
- 2 bit sign, 6 bits codeword select
- Fast-Walsh-transform like decoder

NAME CHANGE UNAVOIDABLE

- QMBOK: Quadrature M-ary Bi-Orthogonal Keying
- QMBOK does not make sense for new modulation
- Not quadrature, not orthogonal (only nearly orthogonal), not bi-orthogonal
- Still 8 chip
- CCK -- Complementary Code Keying

DIFFERENTIAL-PHASE MODULATE CODEWORDS



- **Like 1 and 2 Mbps**
- **Noncoherent Rcvr Enabled**

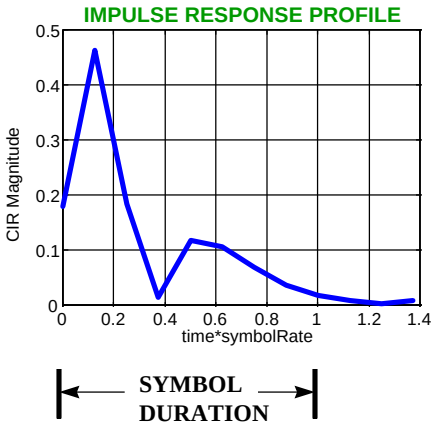
RAKE DESIGN RULES

RULE	HIGH-RATE INDOOR WLAN	VIOLATION PENALTY
Symbol Duration Must Be Much Greater Than Multipath Spread	200 nsec gives 0.25 - 0.5 Symbol Overlap	RAKE ISI Breakdown
Autocorrelation Must Be Impulsive And Cross Correlation Zero	8-16 chips is too small to be effective	Freq. Selective RAKE ICI Breakdown

RECOMMENDED RAKE RCVR EXTENSIONS

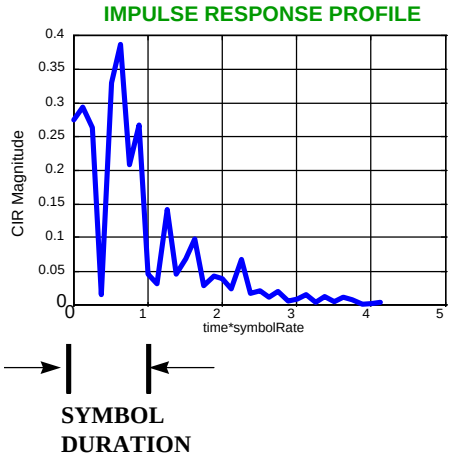
- RAKE rcvr alone works great for 1 and 2 Mbps
- At high data rates, multipath impairments limit the performance of a RAKE
- HARRIS/LUCENT recommend extensions which enable high-performance at 11 Mbps

INDOOR MULTIPATH EXAMPLE



100 nsec RMS Delay Spread

INDOOR MULTIPATH EXAMPLE

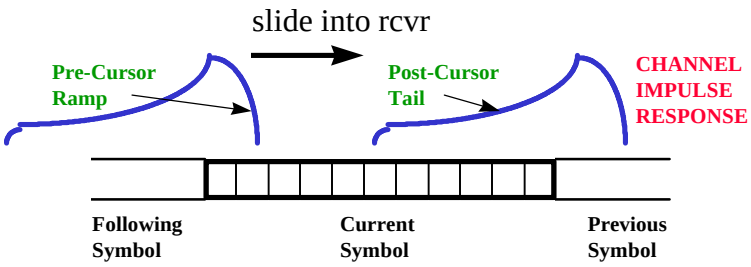


300 nsec RMS Delay Spread

ENVIRONMENT:
COMMERCIAL/ FACTORY

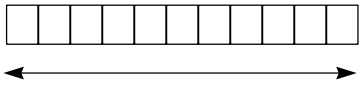
MULTIPATH: ISI LOSS

- InterSymbol Interference (ISI)
- Symbols Smeared Together
- Previous Symbol: Post-Cursor ISI
- Preceding Symbol: Pre-Cursor ISI
- Primary RAKE Failure Mechanism for 802.11



MULTIPATH: ICI LOSS

- InterChip (sub-symbol) Interference (ICI)
- Chips Smeared Together
- Previous Chip: Post-Cursor ICI
- Preceding Chip: Pre-Cusor ICI
- Codeword Orthogonality Lost
- Codeword Equal-Energy Lost
- Secondary RAKE Failure Mechanism for 802.11



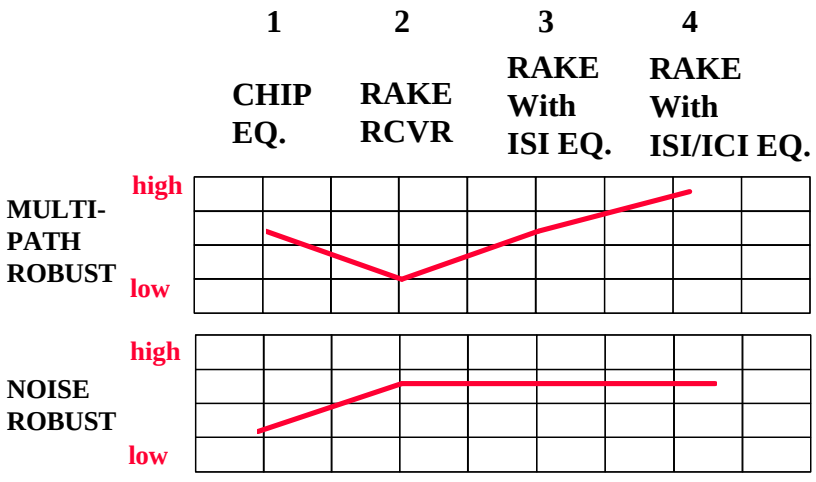
ISI/ICI MITIGATION IN PRE-JULY PROPOSALS

LUCENT	HARRIS	ALANTRO	MICRILOR
• Codeword Design • TSE/MS MLSE	• Codeword Design • CHIP DFE • MLSE/DFE	• Rate 1/2 CODE • MLSE/DFE	• Codeword Design

HARRIS/LUCENT
- Codeword Design
- RAKE with ISI/ICI Equalizer

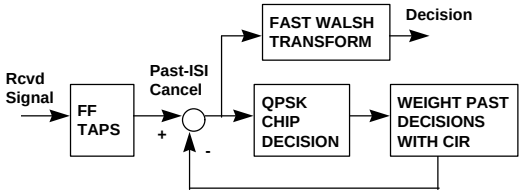
JULY'S PROPOSAL

CANONICAL ARCHITECTURES



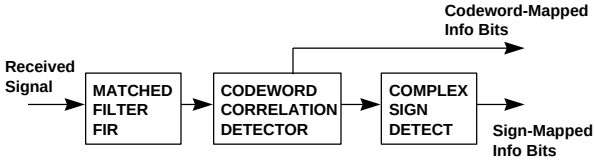
CHIP EQUALIZER

- 2 FF Taps (multiplies) and 10 FB Taps (adds)
- Sliding DFE algorithm minimizes FF Taps
- Lowest-complexity architecture
- 226 nsec multipath-spread testpoint at 11 Mbps
- 20.5 dB SNR testpoint at 11 Mbps (64 byte)



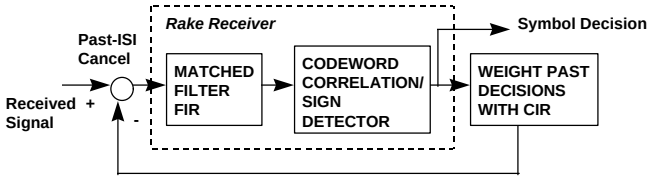
RAKE RECEIVER

- 6 tap Channel Matched Filter
- Second-lowest-complexity architecture
- 90 nsec multipath spread testpoint at 11 Mbps
- 15.5 dB SNR testpoint at 11 Mbps (64 byte)



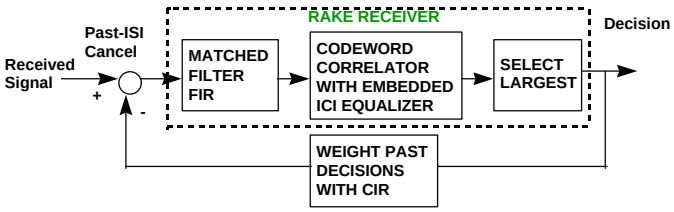
RAKE WITH ISI EQUAL.

- 6 tap Channel Matched Filter
- Third-lowest-complexity architecture
- 144 nsec multipath spread testpoint at 11 Mbps
- 15 dB SNR testpoint at 11 Mbps (64 byte)

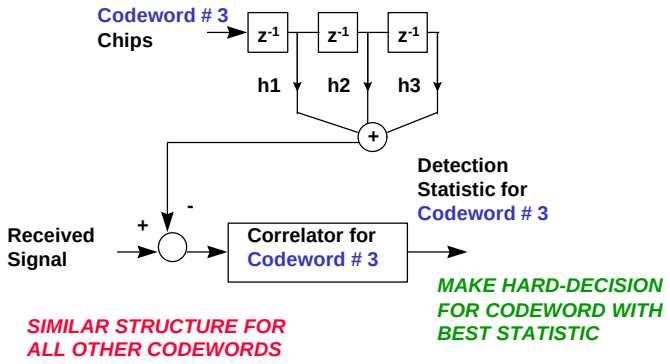


RAKE WITH ISI/ICI EQUAL.

- 6 tap Channel Matched Filter
- Highest-complexity architecture
- 333 nsec multipath spread testpoint at 11 Mbps
- 15.5 dB SNR testpoint at 11 Mbps (64 byte)



RAKE WITH ISI/ICI EQUAL. CORRELATOR DETAIL



PER FOR MULTIPATH AND NOISE

	5.5 Mbit/s - CCK	11 Mbit/s - CCK
Equalized Sliding DFE nFF=2, nFB=10		
Trms at PER=10%, noise free, 64b	226 nsec	186 nsec
Eb/No at PER=20%, with Trms at 10%, 64b	20.7 dB	21.2 dB
Trms at PER=10%, noise free, 1000b	221 nsec	183 nsec
Eb/No at PER=20%, with Trms at 10%, 1000b	25.2 dB	24.7 dB
RAKE with 6 tap CMF		
Trms at PER=10%, noise free, 64b	273 nsec	90 nsec
Eb/No at PER=20%, with Trms at 10%, 64b	14.8	15.2
Trms at PER=10%, noise free, 1000b	226 nsec	65 nsec
Eb/No at PER=20%, with Trms at 10%, 1000b	18.5	17.5
RAKE ISI Equalizer w/ 6 tap CMF		
Trms at PER=10%, noise free, 64b	509 nsec	144 nsec
Eb/No at PER=20%, with Trms at 10%, 64b	16	15
Trms at PER=10%, noise free, 1000b	430 nsec	87 nsec
Eb/No at PER=20%, with Trms at 10%, 1000b	19	17.5
RAKE ISI/ICI Equalizer w/ 6 tap CMF		
Trms at PER=10%, noise free, 64b	Not Needed	333 nsec
Eb/No at PER=20%, with Trms at 10%, 64b	Not Needed	15.5
Trms at PER=10%, noise free, 1000b	Not Needed	226 nsec
Eb/No at PER=20%, with Trms at 10%, 1000b	Not Needed	17.7