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2.4 GHz High Rate PHY

Harris Submission

Brief

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Introduction

- Harris proposes the MBOK waveform previously described in 97-144.
- The waveform has been implemented in silicon and extensively tested.
- Complexity can be traded for performance

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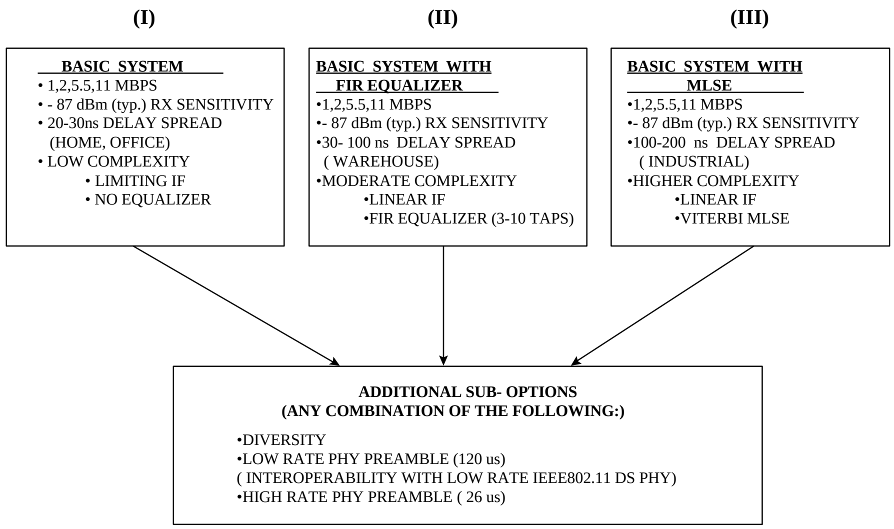
SYSTEM ARCHITECTURE OPTIONS



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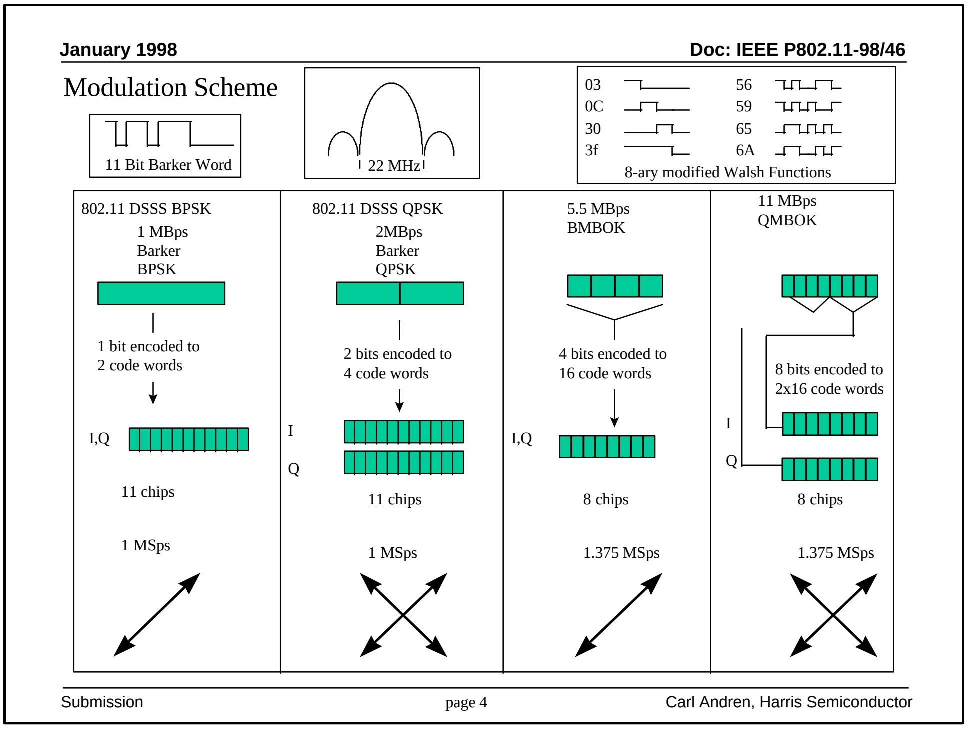
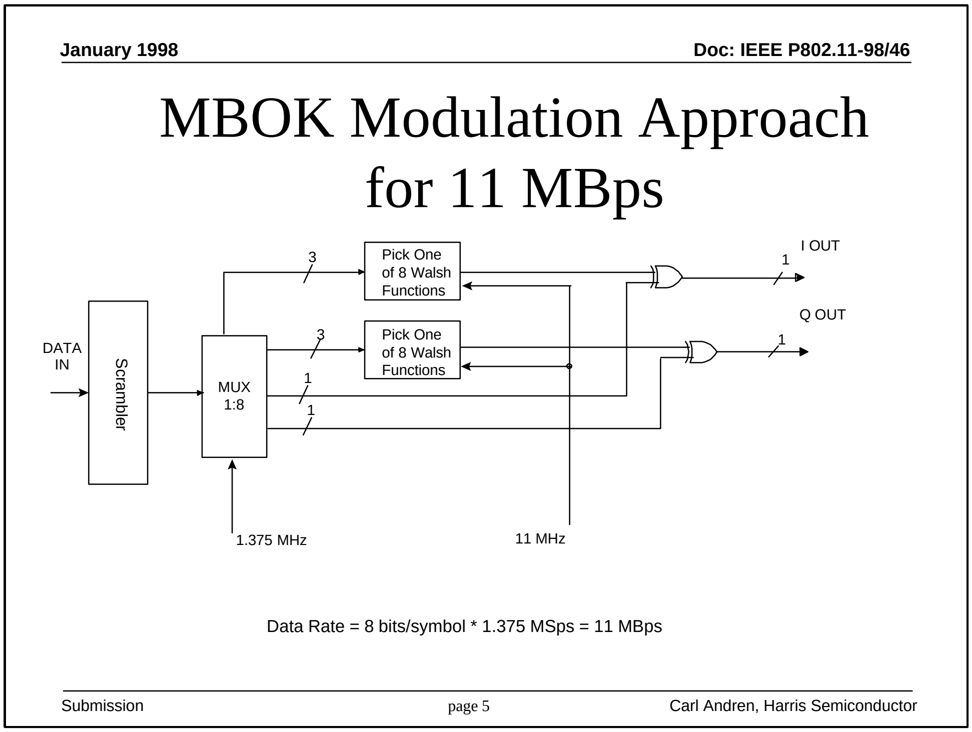


The Harris suggested high rate modulation is a form of M-ary Bi-Orthogonal keying. We propose that both Binary and Quadrature forms of this modulation be used to provide multiple rates for stressed links.



This slide shows how to form our suggested modulation type. M-ary orthogonal keying has been known for many decades, and indeed, can be shown to be a generalization of many standard waveforms such as FSK. In this scheme, the spread function is picked from a set of M orthogonal vectors by the data word. Since the I and Q channels can be considered independent when coherently processed, both can be modulated this way. That allows us to pack 8 bits into each symbol. The most well known orthogonal vector set is the Walsh function set. It is available for 8 and 16 chip vectors and has true orthogonality.

To make the modulation have the same bandwidth as the existing 802.11 DS modulation, the symbol rate is increased to 1.375 MSps while the spread rate is kept at 11 MCps. This makes the overall bit rate 11 MBps.

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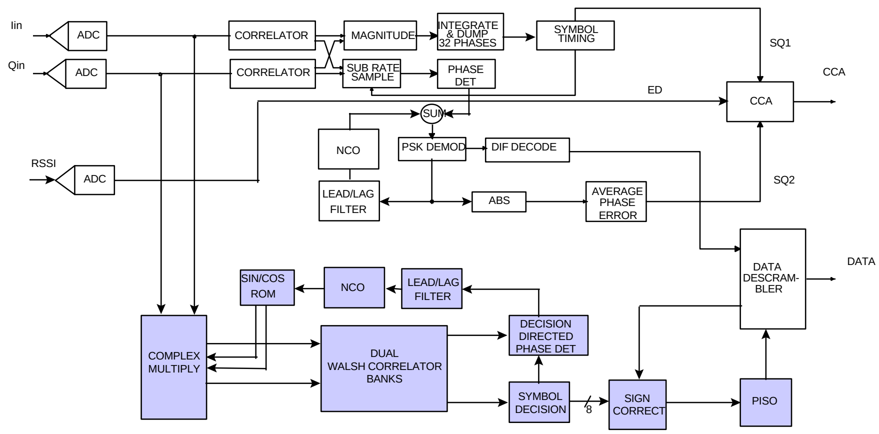
HFA 3860 DEMODULATOR BLOCK DIAGRAM



SHADED BLOCK ARE THE ADDITIONS FOR HIGH RATES

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Implementation Complexity

- Uses same RF and IF as existing 802.11 DS PHY
- Has moderate impact on baseband processor complexity. About 25% extra circuitry for a fully backwards compatible version
- Equalized version replaces the IF limiter with AGC and has more A/D converter bits. It also has about 100% more baseband processor circuitry, which is a 15% increase in radio complexity

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FCC Issues

- An issue has been raised as to the technique's ability to achieve FCC acceptance
- The FCC's CW Jammer and several alternative jamming margin tests have been successfully passed at an independent testing lab.
- FH jamming is essentially the same as CW as shown on the following slide
- The FCC is presently evaluating the hardware in their lab.
- An option exists to use OQPSK for the modulation which would make the spreading 16 chips per symbol

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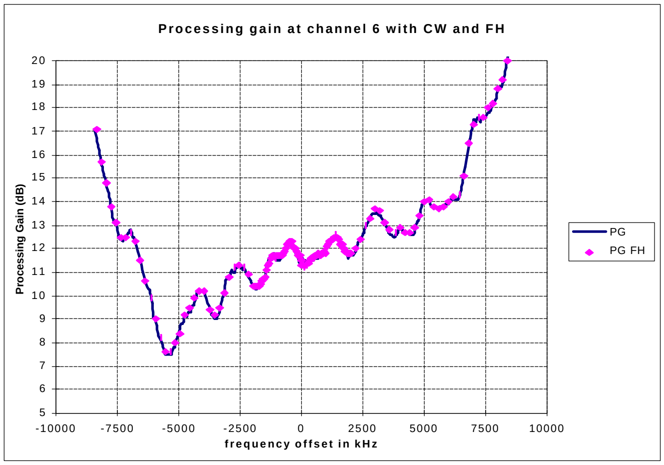
CW Jammer test data

Data shows that the performance is virtually identical with FSK and CW Jamming

Note: channel 1 data is better

The 20% discard point is 10.3 dB



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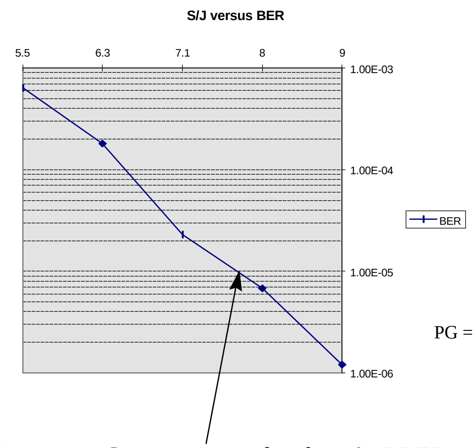
WB Noise Jamming Margin



PG = 16.6 + 2 - S/J = 10.9dB

Note: Processing Gain is measured at the 1.0e-5 BER point
S/J is measured in spread rate bandwidth

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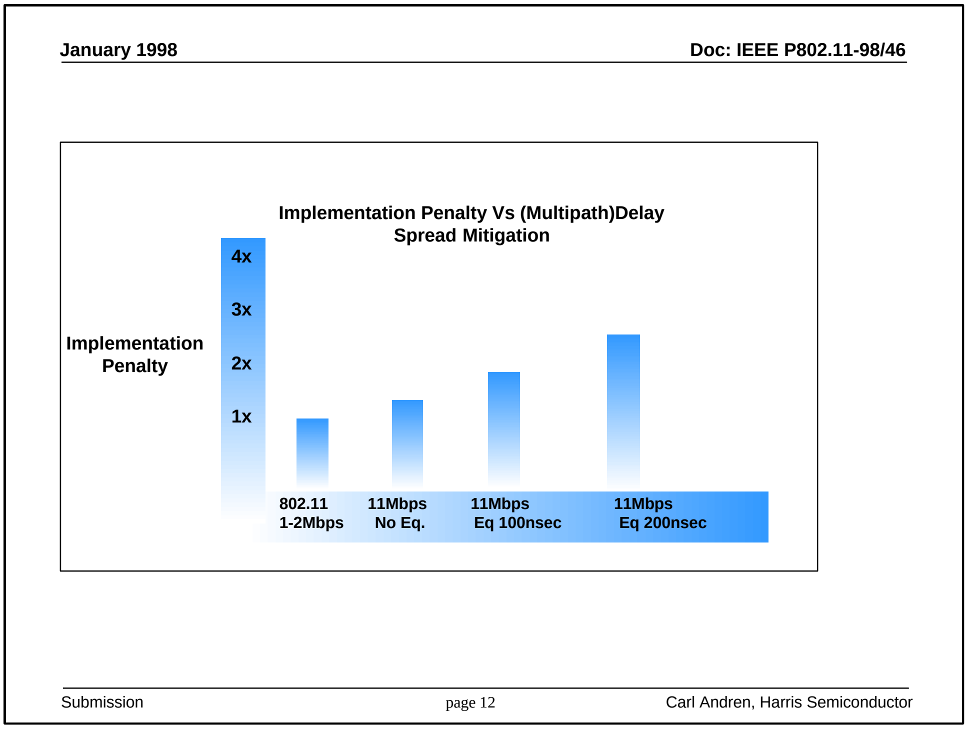
Optional Architectures

- There is a need for a higher delay spread tolerance than any of the proposed waveforms can supply in their basic form.
  - A reasonable equalizer architecture has been identified that will allow 100 ns delay spread
  - A new diversity algorithm and decision metric measurement technique has been identified.



This waveform can work without the need for a channel estimator or equalizer for those channels such as office buildings and homes where the delay spread is small. This makes for the lowest cost implementation.

Where improved performance or longer delay spread is needed, a simple channel estimator and cross sub channel interference suppressor can be added with a nominal increase in baseband processing cost.

When robust performance is needed, a complex channel corrector capability can be added without changing the basic radiated waveform or preamble.

The benefits of a good high rate waveform are an increased longevity in the marketplace and no obsolescence of the early entries. By making the units interoperable, they can be introduced seamlessly into the market. Keeping the channel distortion correction in the receiver allows the system designer to choose only the degree of performance needed for the job.

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Performance Analysis

- A reference radio using the new Harris waveform has been constructed and tested
- The testing shows that the simulated results for multipath are accurate. They show about a 30-50 ns delay spread capability which agrees with the simulation results presented in November.
- Analysis shows that 100 to 200 ns can be achieved with various degrees of equalizer complexity

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Equalizer Options

- An equalizer using 5 taps can improve the multipath performance of the basic design to 75 ns at 10 % PER.
- The zero forcing equalizer structure needs 2 complex adds per feedforward tap and two complex multiplies per feedback tap.
- The gate count for a design that meets 20 % PER at 100 ns with 2 FF and 6 FB taps is 35 K gates

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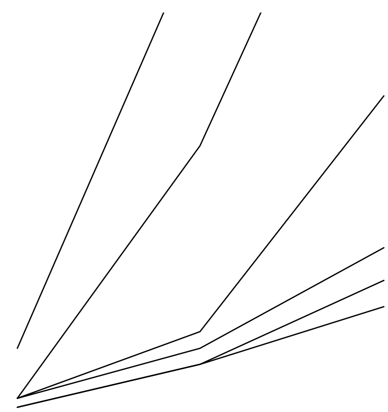
Moderate Multipath Options



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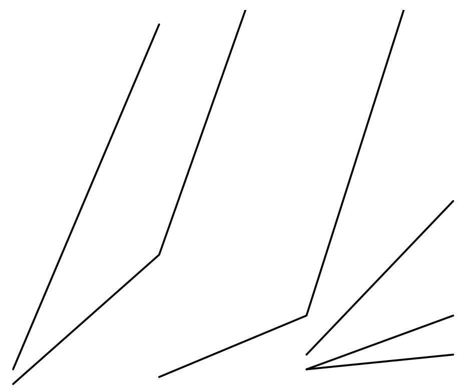
Severe Multipath Performance



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Equalizer Options

Table 3.8-1 Packet error rate performance.

RMS Multipath Spread	10% PER	20% PER
25	ZF DFE, 1 FB Tap	
50	ZF DFE, 2 FB Taps	
75	ZF DFE, 2 FF and 4 FB Taps	ZF DFE, 4 FB Taps
100	ZF DFE, 3 FF and 6 FB Taps or 4 state Viterbi-DFE, 4 FB Taps	ZF DFE, 2 FF and 4 FB Taps
125	4 state Viterbi-DFE, 6 FB Taps	ZF DFE, 2 FF and 6 FB Taps
150	4 state Viterbi-DFE, 8 FB Taps or 16 state Viterbi-DFE, 4 FB Taps	ZF DFE, 2 FF and 8 FB Taps
175	16 state Viterbi-DFE, 7 FB Taps	4 state Viterbi-DFE, 7 FB Taps
200	16 state Viterbi-DFE, 8 FB Taps	4 state Viterbi-DFE, 8 FB Taps

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Diversity Options

- Antenna diversity can improve the performance of the link more cheaply than an equalizer
- A good metric is a necessity for making the diversity decision
- The metric should include quadrature channel information that is missing in the BPSK preamble
- One way to get the information is to include

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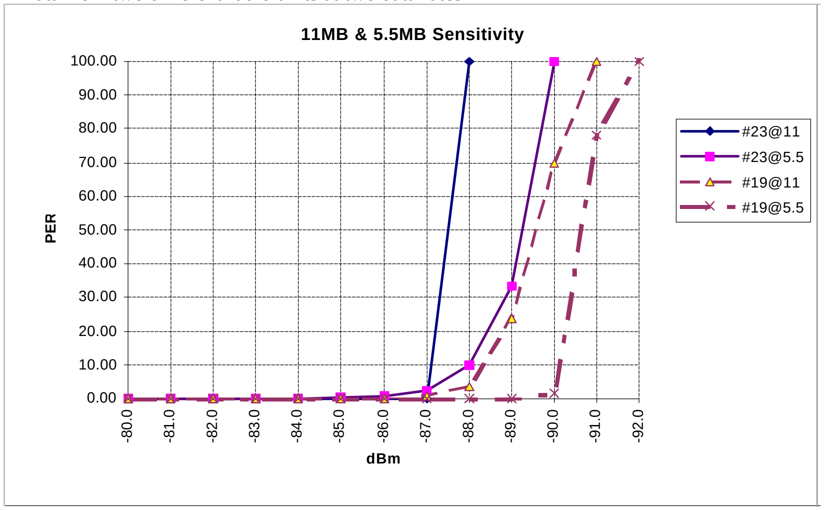
Receiver Sensitivity

Data from two different radio units at two data rates



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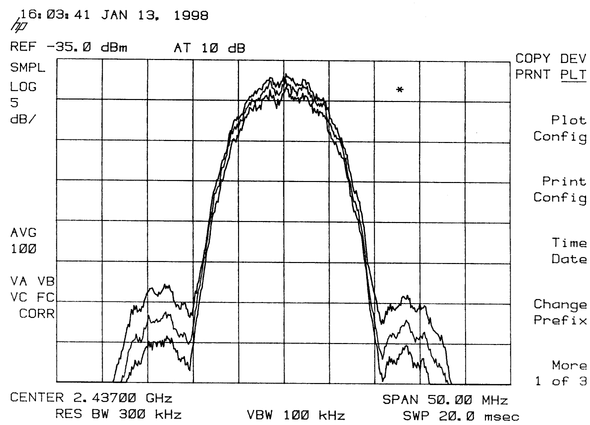
Transmit Spectrum with Backoff

Shows effects of reduced PA Backoff. The amplifiers have been adjusted to 1, 2, and 3 dB of overdrive



A conclusion is that the Backoff is not an especially sensitive parameter for spectral containment

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Co Channel Interference, DS

- The ability of the modulation to tolerate other networks in the area was tested. The results for S/J in dB that causes 5% PER are:

Signal → / Jammer ↓	1	2	5.5	11
1	6.2	7.6	6.9	8.7
2	4.2	6.5	4.0	6.7
5.5	0.9	4.9	3.0	7.9
11	0.9	3.1	1.9	6.8

This indicates that the worst case Jammer for 11 MBps is the 1 MBps waveform that spoofs the preamble.

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The ability of the signal to take jamming by a like signal will impact the ability to collocate nets. This set of data shows how the system will tolerate other DS signals of the various rates.

From the data we can see that the 1 Mbps radio is little effected by the higher rates since they are non correlating. On the other hand, the 1 Mbps radio jams the preamble of all the higher rates better than any other.

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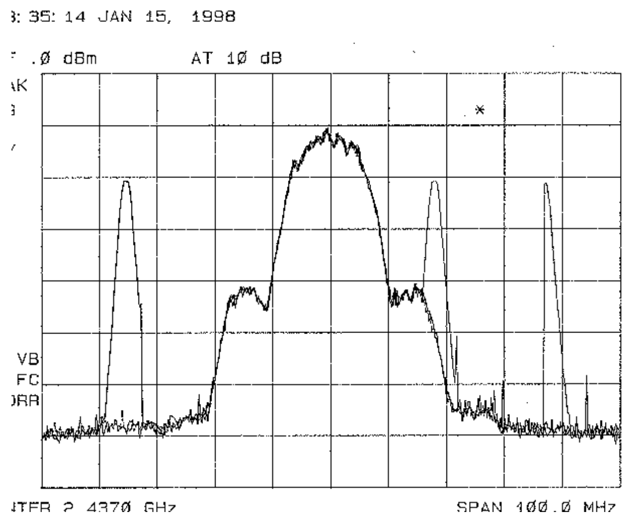
Co-Channel Interference, FH



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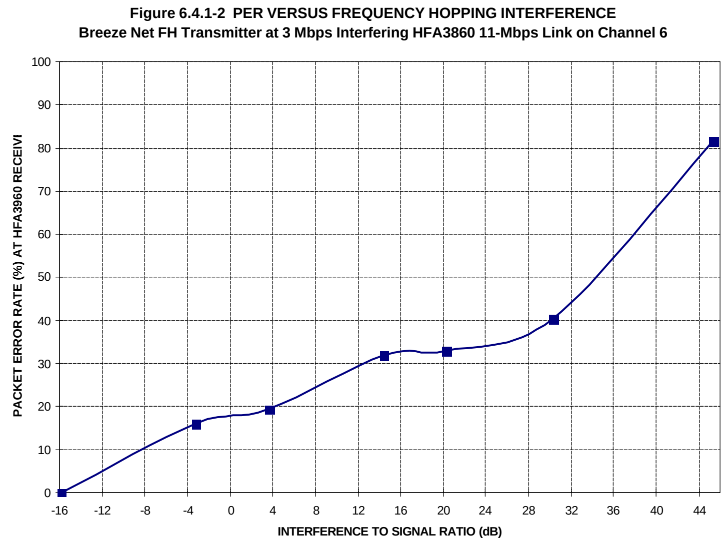
Co-Channel Interference, FH



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Adjacent Channel Interference

- This performance is slightly worse than the performance of a radio designed to the 802.11 standard due to the ~6 dB higher required operating SNR.
- The adjacent channel performance is strongly dependent on the RF and IF components in the transmitter and receiver

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Interoperability

- Our basic approach is to include the standard 802.11 preamble and header
- For the cases where interoperability is not an issue, short, high rate headers can be used.
- Antenna diversity and equalization require a somewhat longer short header than the shortest possible.

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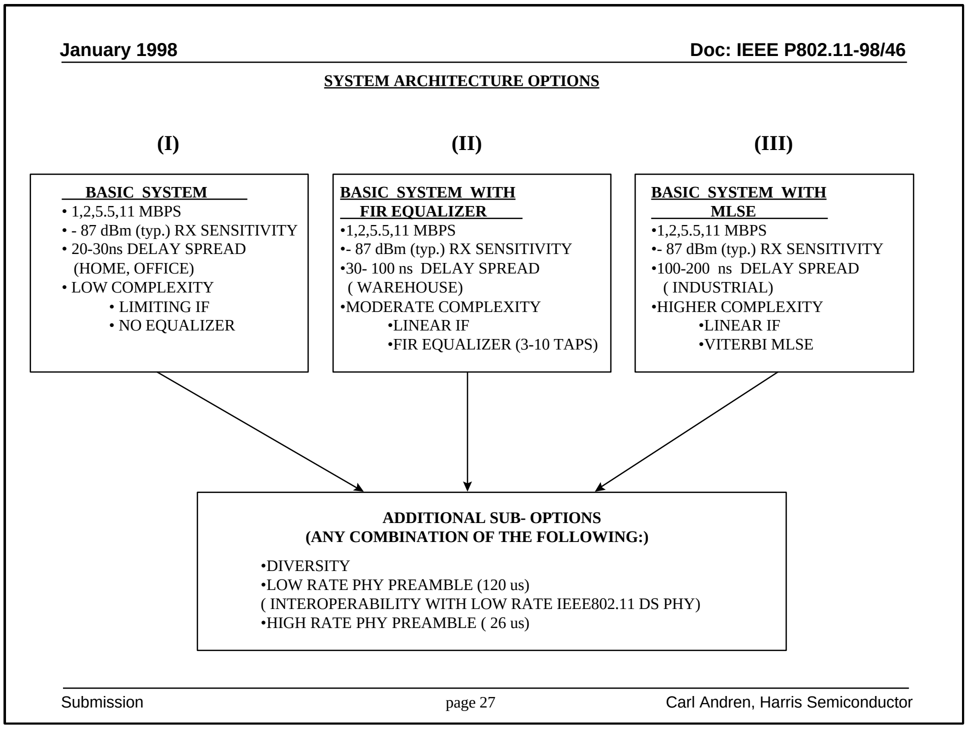
Variations in the Waveform

- There are variations to the chosen sequences for better multipath performance. The performance gains are slight, however.
- It has been suggested that the FCC might accept that the same waveform but using offset QPSK is 16 chips per symbol (22 MCps spread rate).
- If the 8 chips per symbol is an insurmountable problem, higher numbers of chips per symbol can be considered at some compromise in the data rate or spread rate, i. e. 10 MBps at 13.75 MCps with 11 c/b. This is a last resort option.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SYSTEM ARCHITECTURE OPTIONS
(I)
(II)
(III)
BASIC SYSTEM
• 1,2,5.5,11 MBPS
• - 87 dBm (typ.) RX SENSITIVITY
• 20-30ns DELAY SPREAD (HOME, OFFICE)
• LOW COMPLEXITY
• LIMITING IF
• NO EQUALIZER
BASIC SYSTEM WITH FIR EQUALIZER
•1,2,5.5,11 MBPS
•- 87 dBm (typ.) RX SENSITIVITY
•30- 100 ns DELAY SPREAD (WAREHOUSE)
•MODERATE COMPLEXITY
•LINEAR IF
•FIR EQUALIZER (3-10 TAPS)
BASIC SYSTEM WITH MLSE
•1,2,5.5,11 MBPS
•- 87 dBm (typ.) RX SENSITIVITY
•100-200 ns DELAY SPREAD (INDUSTRIAL)
•HIGHER COMPLEXITY
•LINEAR IF
•VITERBI MLSE
ADDITIONAL SUB- OPTIONS
(ANY COMBINATION OF THE FOLLOWING:)
•DIVERSITY
•LOW RATE PHY PREAMBLE (120 us)
(INTEROPERABILITY WITH LOW RATE IEEE802.11 DS PHY)
•HIGH RATE PHY PREAMBLE (26 us)
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