IEEE 802.11
Wireless Access Method and Physical Specification

Title: **Issues and Trade-offs in High Speed 2.4 GHz PHY**

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Introduction

Isues, concerns, and trade offs for a HS PHY in the 2.4 GHz band from a different viewpoint
- Interoperability with both FH and DS
- Interference and need for multiple channels
- Multipath
- 1 vs 10 Mbps preamble and PLCP header
- Low cost and need for architectural option

Our alternative proposal would more effectively address these issues+
- DS spreading format
- Modulation and channelization
- Hopping and interoperability with 1&2 Mbps FH PHY
- Interoperability with 1&2 Mbps DS PHY
- Rate switching, 1 vs 10 Mbps preamble and PLCP header
- Comparison to 1&2 Mbps FH PHY
- Low cost, many architectural options

Subsequent submissions will address performance simulation/measurements

Interoperability with both FH and DS

The high speed study group has decided in previous motions that there will be only one high speed PHY at 2.4 GHz

- Given the relatively large number of installed users of 802.11 ready FH PHY systems, it would be advantageous to provide compatibility with FH PHY systems as well as DS PHY systems

Obviously, given the different bandwidths of DS signals versus the 1 MHz FH PHY signals, there will be limited interoperability

- However, it is more than feasible to design units that can accommodate wideband and narrowband signals with the right definition
- Provisions for hopping and non-hopping will greatly enhance the ability of both FH and DS PHY to be at least partly interoperable with the high speed PHY

Interference and need for multiple channels

As a manufacturer of both DS and FH systems, we have found that interference has necessitated the use of frequency agility even in DS systems

- Especially as the band got more crowded as occurred at 900 MH
- This will also happen soon in the 2.4 GHz band

Having multiple channels to use should be a requirement for the high speed PHY

- Having a mechanism to hop over the channels will be a big advantage as has been shown in the FH systems fielded today
- Frequency selectivity can provide typically 60 to 70 dB of isolation between channels

Direct sequence processing gain will also make the demodulator more robust because of Hamming distance

Multipath and Robustness vs Bandwidth

Multipath distortion at the wider bandwidths requires the most robust modulations to mitigate its effects

Binary modulations are more robust than quadrature modulations, but requires twice the bandwidth

- 10 Mbps would require 10 Mcps with QPSK and 8 chips/symbol and bandwidth of 20 MHz null to null
- BPSK would use 20 Mcps with bandwidth of 40 MHz null to null
- MSK would be in between at about 30 MHz
- 16 chips/symbol would require about 60% more bandwidth, i.e., 32, 64, and 48 MHz

Binary FSK is one of the most robust modulations as the receive capture effect approaches 0 dBc in theory

- Binary GFSK also provides narrow bandwidth, e.g., a 20 Mcps FSK would have a 10 dB bandwidth approximately 22 MHz

DS processing will improve multipath performance in all cases above

1 vs 10 Mbps preamble and PLCP header

The option to have 1 Mbps preamble is desirable, but the high overhead makes it difficult to achieve high throughput efficiency except in large packet situations

The option to be able to operate with 10 Mbps preamble, i.e., about 10% of the 1 Mbps preamble, would be necessary to meet expectations on throughput increases

Coherent QPSK operation with separate chipping sequences on I and Qwould require a longer preamble than the current DS PHY single chipping sequence (same on I and Q) over BPSK/QPSK

FSK would not require a longer preamble nor would it preclude it

Low cost and many architectural options

There are many applications that could use wireless LANs

- These applications will span a wide range of requirements except for the common requirement of the lowest cost possible

The high speed PHY should allow for optimizing architectures to provide the best price/performance possible

- Better than forcing all applications to take a one size fits all solution.
- This will increase the target market for the HS PHY beyond what would be feasible with the one size fits all approach

High Speed PHY Proposal

A succinct summary of the proposed high speed DS PHY is as follows:

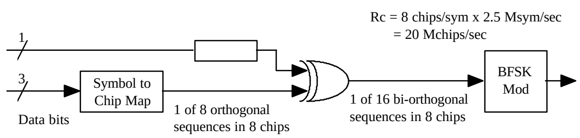
- DS spreading: 4 bits/symbol and 8 chips/symbol bi-orthogonal Walsh codes
- Modulation: Binary GFSK with deviation h=0.7; 1.5 dB preemphasis
- Data rates: 1.25 Msym/sec (5 Mbps) and 2.5 Msym/sec (10 Mbps)
- Chipping rates: 10 Mcps and 20 Mcps
- Bandwidths: 11 MHz and 22 MHz

DS Spreading Format

The DS spreading formats used by Harris and Micrilor uses simple yet effective bi-orthogonal Walsh codes

The 8 chips per symbol used by Harris is more bandwidth efficient which is crucial to satisfy the interference fighting channelization mentioned earlier

The 4 bits/8 chips per symbol used at 1.25 (or 1.375) Msps and at 2.5 Msps would produce 5 and 10 Mbps at a chipping rate 10 and 20 Mcps

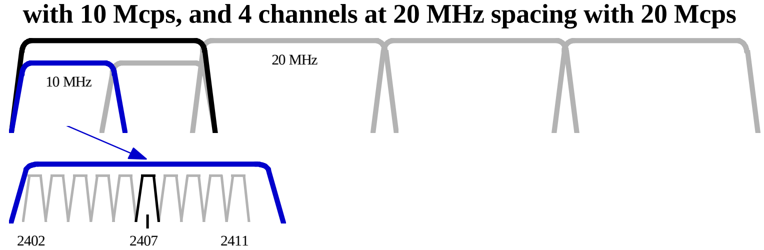


Modulation and channelization

The proposed modulation format is binary GFSK at 10 and 20 Mcps with a deviation of 7 and 14 MHz peak to peak (h = 0.7)

- The 10 dB bandwidth is roughly 11 and 22 MHz
- The modulation uses a combination of preemphasis and filtering to balance interference and multipath performance with desired spectral bandwidths

The channelization plan consists of 8 channels at 10 MHz spacing with 10 Mcps, and 4 channels at 20 MHz spacing with 20 Mcps



Hopping and interoperability with 1&2 Mbps FH PHY

- **The hopping can be synchronized to interoperate with the 1 and 2 Mbps FH PHY**
- **There are ten 1 MHz channels in each 10 MHz wideband channel and twenty in each 20 MHz wideband channel**
- **When a particular 1 MHz channel is hopped to, the wideband channel which covers that 1 MHz channel is also used**

Interoperability with 1&2 Mbps DS PHY

- **The bandwidths proposed would be compatible with the current 11 Mcps used in 1 and 2 Mbps DS PHY**
- **The DS PHY already provides for frequency selection interface with the MAC, similar to that used by the FH PHY (sans hopping algorithm)**

Interoperability with 1&2

- **The proposed format can use existing DS chip sets and architecture with changes primarily in the baseband processing to have a DS/HS design**

Rate switching, 1 Mbps vs high speed preamble and PLCP header

It is possible to use the current FH 1 Mbps preamble and switch to high speed operation after the PLCP header

- The remaining spare bit in the PLCP header could be used to indicate a x5 multiplier of the rate field
- The same tradeoffs of 1 Mbps preamble for interoperability and CCA discussed in the DS proposals apply
- Similar features can be made for DS preamble

Because of the bandwidth differences, it is preferable to use high speed preamble not only for overhead efficiency but also for the ability of FH/HS units to perform proper CCA on the HS signal

- For FH/HS BSS's that may be using different hop sequences and tuned to a different 1 MHz channel within the same wideband channel, a high speed preamble would be better for implementing CCA on both narrowband and wideband channels.

Sensitivity vs 1&2 Mbps FH

The Eb/No required of an FSK signal with an h=0.7 is 7 dB less than the 1 Mbps FH PHY which uses an h=0.32.

With a data rate of 5 Mbps, the noise bandwidth is 7 dB greater and the resulting signal requires a signal equal to that of the 1 Mbps FH PHY signal.

- The increase in bandwidth due to the DS spreading would be more than made up for in the despreading process.
- Thus the range of the 5 Mbps mode would be equivalent to the 1 Mbps FH PHY on a signal sensitivity basis alone, but will be degraded by the increase in multipath distortion and interference susceptability.

10 Mbps would be degraded by an additional 3 dB and even wider bandwidths and thus susceptability to interference and multipath.

Interference and multipath

As mentioned earlier, narrower bandwidths, availability of multiple channels, and mechanisms to automatically hop among channels are all useful means by which to combat interference and multipath.

The binary GFSK modulation would allow the narrower bandwidth in the 5 Mbps mode, and the 10 Mbps would have a maximum 22 MHz bandwidth with a robust binary non-coherent FSK modulation.

Low cost, many architectural options

An FSK system has been the lowest cost due to the simplicity, inherent robustness, and use of nonlinear components.

There are many options and design optimizations which will allow manufacturers to optimize for various applications and price/performance tradeoffs.

Intellectual property - Walsh codes and binary GFSK on wireless is probably not patentable any more.

Feature Comparison Table

Feature	Harris	Micrilor	Symbol
Modulation	MOK BPSK/ coh QPSK	MOK BPSK (MSK?)	MOK BGFSK
Data rates	5.5/11 Mbps	5/10 Mbps	5/10 Mbps
Bandwidths	22 MHz	32/64 (24/48?) MHz	11/22 MHz
Number of channels	3/3	2/1 (4/2?)	8/4
Interoperability with FH	None	None	Partial
Interoperability with DS	Yes	None	Partial
Short preamble capable	?	Yes	Yes
Max J/I			
Multipath			