Frequency Hopping Spread Spectrum PHY

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Introduction

This contribution is intended to provide an overview of a FHSS PHY and outlines the criterias for defining this PHY. The final specifications have to be worked out in conjunction with the MAC definition and the agreed channel model. Committee members are welcomed to provide their inputs to the completion of this document.
At the end of this paper, there are some experimental facts and a link calculation example.

Requirements outline:

Compliance with Regulatory Agencies for unlicensed operation

Compliance with 802.11 PAR (Data Rate at least 1 Mbps, etc.)

Operation in a multinetwork environment (multiple collocated networks)

Minimum Area coverage

Suitable for low power consumption implementations

Cost effective

Modes of operation:
- peer to peer with no prior knowledge
- node to AP and AP to node

Support asynchronous and time deterministic connectivity.

Support a specified number of stations per cell (Access Point)

Suitable for small size implementation

Robust operation in narrow band and partial band interference as well as multipath fading.

Graceful degradation under load and interference.

What FH can offer:

Being an avoidance type system offers better robustness than other SS techniques with low processing gain (as the ones that could be used in the ISM bands).

Less susceptibility to "Near Far" problem.

Can provide the largest amount of band spreading.

Relatively short acquisition time.

Non coherent modulation techniques used, lend themselves towards simpler implementations therefore low cost.

Can provide best distance performance with an optimized receiver

Robust operation in presence of Narrow band or partial band interference.

Multipath environment operation: "Natural frequency Diversity"

Multiple Networks through CDMA

Specifications

The following table presents an example of Frequency Hopping PHY specification. I left several blanks for those items that can be determined only after the channel model is agreed by 802.11 and PHY MAC interface requirements determined; Other parameters have to be worked out between PHY and MAC groups.

PARAMETER	Required Spec.	Proposed Spec.	Comments
Frequency Range	2.4 to 2.4835 Ghz	2.4 to 2.4835 Ghz	Other frequency bands will follow.
Minimum number of frequencies	75	75	per FCC part 15.247
No of hops per sec.	2.5 min. (FCC 15.247)	4	
Transmitted power		1000, 250, 100, 50 mW	Power levels dependent on the specific applications
Max. Radiated EIRP		6 dBW in US ? dBW in Europe	Total radiated power including antenna gain Normally defined by regulatory agencies in each country.
Transmitted power variation (tolerance)	TBD dB	+0 /-3 dB max. (total)	
Receiver Sensitivity		-80 to -90 dBm	Final number TBD after channel and link model agreed
Max. Input signal level at antenna connector with no performance degradation	TBD dBm	0 dBm	
Adjacent Channel selectivity		-25 dB at channel boundary -65 dB @Δf=2 MHz	
Channel bandwidth (allocated)		1 MHz	
Occupied channel bandwidth (spectrum shape)		30 dBc @ Δf=.5 MHz 86 dBc @ Δf=2 MHz	
Data Rate	1 Mbps	1 Mbps	Higher data rates not recommended because of delay spread and bandwidth constraints
Spurious emissions in band (@ Δf1 MHz from Fc)		-80 dBc @ 100 mW TX power	
Spurious emissions out of band	-20 dBW in US - 60 dBW/100 kHz @ 1 to 10 Ghz -66 dBW/100 kHz @ 30 MHz to 1 Ghz		dependent on country

Switching time TX to RX			Time from full power transmission to full sensitivity receiver availability. This parameter should include any preamble time used for receiver synchronization.
Switching time RX to TX			time from full sensitivity reception to full power transmitter availability
Channel switching time (hop settling time)		typically 100 to 200 S	Elapsed time from receipt of hop command until unit frequency settles within +/- F= Receiver Acceptance range or TX frequency tolerance (whichever is tighter)
Modulation		4 level FSK	
Demodulation		Non coherent	
BER at specified Eb/No	10 exp. -6	10 exp. -6 @ Eb/No=17 dB	
Channel availability		99.5 %	Could also be specified as probability of outage. With no interference.
TX Frequency Stability		15 ppm	
Receiver Frequency Acceptance Range		+/- TBD Hz	
Data Line/ Clock Input/Output Jitter			Include static and dynamic jitter (see 802.3 definition) This parameter has to be negotiated with MAC group.
Min. reception range		333 feet	Conditions TBD
Max. Required range (For applications where no AP's are available)		1000 feet	Conditions TBD
Antenna port impedance		50 ohms	
VSWR		Devices shall stand 0VSWR with no damage. -Operational VSWR =TBD	
Interface to MAC		RX Data TX Data RX/TX clock Frequency control TX/RX switching Signal Quality Net Management info.	Timing and logic levels TBD.
Safety Requirements		Compliance with applicable Safety Agencies requirements	

Field Experience

Superior performance in presence of interference, both narrow band and partial band. Up to 60 dB I/S in adjacent channels.

Good propagation characteristics in indoors environments. @ 1 W. TX power indoors range up to 1000 ft., outdoors range 6 miles with std. monopole antennas and retries protocol.

Guaranteed data delivery with retries (Several systems tested in the field over more than nine months @250 Kbps data rate with interference present. In some sites a number of microwave ovens were in normal use)

Conclusions:

Frequency Hopping Spread Spectrum provides an economical, technically feasible solution meeting the requirements for a wireless LAN. When coupled with a suitable protocol it exhibits superior performance in the presence of narrow band and partial band Interference and Multipath propagation as proven by field experience.

Link Calculations Example

See attached spread sheet.

RADIO LINK CALCULATIONS 0.0621 MILE HOP--(IEE 802.11)

SYM	PARAMETER	2460 MHz A-B LIRECTI	B-A DIRECTION
1. Pt	Transmitter power output	0.25 watt(	0.25 watt(s)
		-6.0 dBw	-6.0 dBw
2. G1	Transmit antenna gain	0.0 dB	0.0 dB
3. G2	Receive antenna gain	0.0 dB	0.0 dB
5. L2	Transmission Line Loss--transmit	1.0 dB	1.0 dB
6. L3	Transmission Line Loss--Receive	1.0 dB	1.0 dB
7. F	Receiver noise figure	10.0 dB	10.0 dB
8. T_e	Receive equiv noise temp (ref to ant port)	35.3 deg K	35.3 dBw
	(290)(F+L1+L3-1)		
9. No	Receive equiv noise density	-193.0 dBw/H	-193.0 dBw/Hz
	No=k(Te+Ta);Ta=290		
	No=kF(290)		
10 EIRP	Transmit EIRP	-7.0 dBw	-7.0 dBw
11 R	Transmission rate	1000.0 Kbps	1000.0 Kbps
12 Eb/No	Modem rqmt for 10-6 BER (4FSK)	15.0 dB	15.0 dB
13 I	Modem implementation margin	3.0 dB	3.0 dB
14 C	Rcvr cxr pwr at threshhold BER	-115.0 dBw	-115.0 dBw
	C=(Eb/No)(I)(No)(R)		
15 Fm	Fade Margin (enter a,b,u,f,d	0.0 dB	0.0 dB
a =	3 (terrain: 4=smooth; 1=norm; 0.25=rough)		
b =	0.4 (climate: 0.5=humid;0.25=norm;0.125=dry)		
Ua-b	0.001000 (path unavailability)	99.9 %	99.9 %
Ub-a	0.001000 (path unavailability)		
16 Lp	Path loss, free space	80.3 dB	80.3 dB
d =	0.0621 mile(s) 328 feet		
f =	2.46 GHz		
17 Lm	Misc unknowns (enter)	0.0 dB	0.0 dB
18 Pr	Actual Cxr Pwr at receiver	-87.3 dBw	-87.3 dBw
	Pr=(Pt)(G1)(G2)/(Fm)(Lp)(Lm)(L1)(L2)		
19 M	Net Path Margin	27.7 dB	27.7 dB