

*Frequency Hopping Spread  
Spectrum subpart of the  
802.11 Wireless LAN  
Standard*

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*802.11-FCC Meeting  
Objectives*

To inform FCC about the 802.11 WLAN  
Standard and its status

To avoid situation in which 802.11 standard  
is not acceptable by FCC

To get better understanding of what FCC  
does permit, in order to produce a better  
standard

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## *Collision Avoidance*

- The Physical layer (PHY) is able to provide Carrier Detect indication, when not transmitting.
- Randomized Inter-Frame Space (IFS) for reducing collision probability
- Exponential Backoff is used to stabilize the network when collisions occur

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## *Virtual Carrier Sense mechanism*

- In radio network, some stations may not hear a transmission from a certain station and therefore collide with it
- The RTS-CTS exchange contains timing information that signals other stations for how long the medium will be busy
- Virtual Carrier Sense mechanism is implemented in the MAC layer

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## *Frequency Hopping Sp.Sp.*

Operates according to FCC 15.247 ruling:

- max 1 MHz bandwidth at -20 dB PSD
- hopping over 79 frequencies in a pseudo-random manner
- max 1 Watt power and 36 dBm EIRP

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## *802.11 FHSS Modulation Objectives*

- Achieving at least 1 Mbit/sec rate
- Low cost/familiar technology - FSK
  - Constant Envelope- Saturated Amplifiers
  - Limiter-Discriminator detection
- Multichannel operation -shaping to reduce adjacent channel interference
- Multiple rates - taking advantage of short range scenarios to increase rate

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## *802.11 FHSS Modulation*

- o Gaussian shaped FSK (GFSK)
  - 1 Msymbol/sec
  - NRZ data is filtered with BT=0.5 Gaussian filter
- o 1 or 2 Mbit/sec with multilevel GFSK
  - 1 Mbit/sec: 2 level GFSK  $h_2=0.34$
  - 2 Mbit/sec: 4 level GFSK  $h_4=0.45h_2=0.15$
  - Preamble and Header always at 1 Mbit/sec; Data at 1 or 2 Mbit/sec

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## *GFSK vs GMSK comparison*

- o GMSK is popular with cellular telephony
- o GMSK is a binary GFSK with  $h_2=0.5$
- o 802.11 GFSK is  $h_2=0.34$  due to both
  - 1 Mb/s objective
  - 1 MHz 20 dB bandwidth 15.247 ruling
- o Results:
  - Sensitivity reduced by 4-5 dB
  - Increased first adjacent channel interference

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## 802.11 FHSS Frame Format



- PHY header indicates payload rate and length;
- CRC16 protected
- Data is formatted to limit DC offset variations, for PLL based implementations

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## FHSS Modulation Specifications

### Deviation:

- Upper bounded by FCC requirements
- Lower bounded to maintain sensitivity

### Shape accuracy:

- Zero crossing instants accuracy
- Level accuracy

### Center Frequency accuracy - 60 KHz

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## *Receiver Performance*

Parameter vs. Rate	1 Mb/s	2 Mb/s
Sensitivity	-80 dBm	-75 dBm
Desensitization		
@ 2 Mhz offset	30 dB	20 dB
@ 3 Mhz or more	40 dB	30 dB
Intermodulation	30 dB	25 dB
Protection		

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## *CCA- Clear Channel Assessment*

### CCA is used to:

- Initiate frame reception
- Avoid transmitting when the channel is busy

### CCA Sensitivity:

- 80 dBm for  $P_r < 20$  dBm, reduced by 0.5 dB for each dB of power increase
- Detection during 0101 pattern within 20 usec with 95% probability

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## *Frequency Hopping Sequences*

### Design Criteria:

- Assured minimum hop distance for multipath diversity performance

- Minimizing hits and adjacent channel hits between different hopping patterns

- Minimizing consecutive hits between different hopping patterns

FCC 15.247 requirement: Pseudorandomly ordered frequency list

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## *Previous Hopping Sequences*

- Previous 802.11 hopping sequences were based on constant frequency increment (mod 79).

- Had better worst case hit, adjacent hit and consecutive hit performance

- Were rejected by FCC as insufficiently pseudorandom (due to constant frequency increment)

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## *New Frequency Hopping Sequences*

- Passed FCC approval for BreezeNet
- Predesigned computer generated pseudorandom list of 79 frequencies
- Minimum hop distance of 6 channels
- Additional hopping sequences derived from the base predesigned sequence.
- 78 hopping patterns organized in 3 sets of 26 patterns each.

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## *New Frequency Hopping Sequences- cont.*

- Denote frequency as  $2402+b[i]$ ,  $b[i]$  is the base sequence in range 0.. 78.
- k-th sequence is formed from the base sequence as  $2402+(b[i]+k) \bmod 79$
- Example:

Base seq: 2402, 2456, 2472, 2447, ...

30-th seq: 2432, 2407, 2423, 2477, ...

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