IEEE 802.11
Wireless Access Method and Physical Specifications

Title: MUTUAL INTERFERENCE BETWEEN FREQUENCY HOPPING PHY AND DIRECT SEQUENCE PHY REVISITED

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1. INTRODUCTION AND SUMMARY

The 802.11 PHY group has decided to work on 3 possible PHY standards. Two are using the same RF spectrum and the third is at IR frequencies. The two PHY implementations at RF are usually referred to by their spreading mechanisms: 1. The Frequency Hopping PHY, and 2. the Direct Sequence PHY. This paper highlights some of the operational issues when these systems are collocated. The IR system is not addressed here as this system is independent at the physical medium level.

The conclusion is that these two PHYs very much impact each others performance, i.e. that throughput and delay through the networks are stongly depending on the proximity, the activity levels of either system, the protocols and signal parameters used.

It is our opinion that it is the responsibility of the standard committee to establish ettiquettes or protocols which assure the customers a certain level of performance when the WLAN consists of all 802.11 compliant PHYs. In other words, if the committee decides to approve two RF PHYs, the standard is to include, as a minimum, rules for these systems to co-exist in a predictable and useful manner.

This paper first describes the sensitivity of the receivers of each system to the signals from the other system. Then the impact on throughput is discussed using some very basic assumptions.

2. MUTUAL INTERFERENCE

The impact of one system on the other is here described in terms of the effective signal to noise ratio. In the next two sections the effective SNR is calculated assuming that the Frequency Hopping signal and the Direct Sequence signal have overlapping spectra. If these two signals occupy non-overlapping spectra, the impact on each others performance can in general be neglected.

2.1 DIRECT SEQUENCE SYSTEM SENSITIVITY TO FREQUENCY HOPPING SIGNALS

If the frequency hopping signal is outside the RF bandwidth of the direct sequence signal, there is no impact on the direct sequence communication.

If the frequency hopping signal is within the RF bandwidth of the direct sequence signal, the net decrease in the SNR at the detector is estimated on the basis of the increase of the noise level at the detector after despreading and symbol integration. This is approximately:

$$SNR_{DS\_DET} = \frac{P_{sign}}{\text{Thermal Noise} + \text{Freq.Hopping Noise}}$$

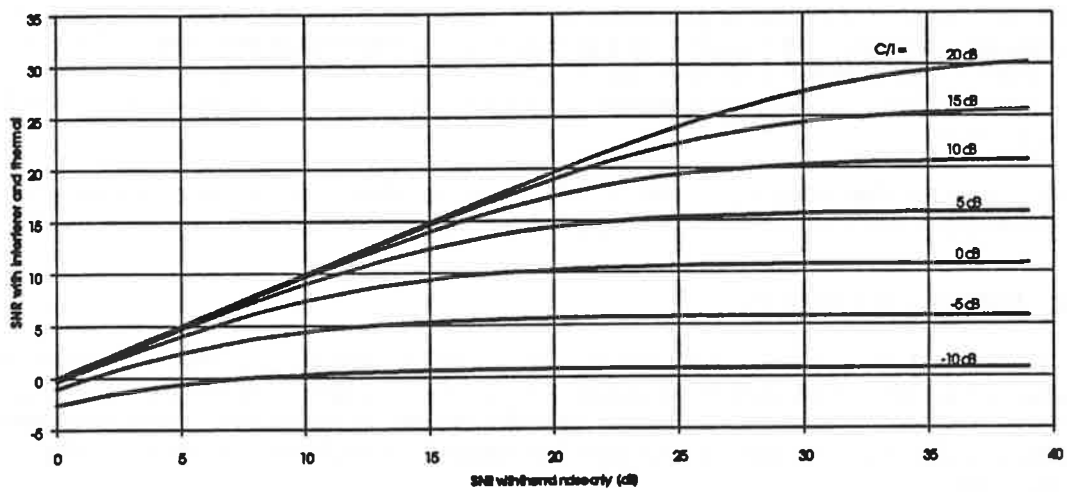
$$= \frac{P_{sign}}{\frac{P_{sign}}{SNR_{DET\_TH}} + \frac{P_{Interferer} \cdot R_{Symbol}}{R_{chip}}}$$

$$= \frac{1}{\frac{1}{SNR_{DET\_TH}} + \frac{1}{\frac{C}{I} \cdot \frac{R_{chip}}{R_{Symbol}}}}$$

with

P_{sign}	- the signal power of the desired signal
$P_{interferer}$	- the signal power of the frequency hopping signal
R_{Symbol}	- the symbol rate of the direct sequence receiver
R_{chip}	- the chip rate of the direct sequence signal
SNR_{DET_TH}	- the signal to noise ratio at the detector of the direct sequence receiver under thermal only conditions
C/I	- P_{sign} / $P_{interferer}$

Effective SNR for Direct Sequence System with Frequency Hopping Interferer
Assumes Frequency Hopping in RF band of Direct Sequence signal
Rchip/Rsymbol = 12



The main conclusion is that the desired signal i.e. the Direct Sequence RF signal power has to be at least 5< to 10 dB stronger than the Frequency Hopping RF signal power for reliable demodulation. This assumes that demodulation with a BER of 10^{-5} requires an SNR of 15 dB or higher.

2.2 FREQUENCY HOPPING SYSTEM SENSITIVITY TO DIRECT SEQUENCE SIGNALS

Again, if the frequency hopping signal is outside the RF bandwidth of the direct sequence signal, there is no impact on the frequency hopping signal. In this paper the interference of the DS transmitter is described in terms of a decrease of the Signal to Noise ratio at the IF. The main variables of interest are the signal strength of the Frequency Hopping signal relative to the Direct Sequence signal, or C/I, and the bandwidth of the two signals. The effective Signal to Noise ratio, SNR_{IF_EFF}, is then:

$$SNR_{IF\_EFF} = \frac{P_{sign}}{\text{Thermal Noise} + \text{Direct Sequence Noise}}$$

$$= \frac{P_{sign}}{\dfrac{P_{sign}}{SNR_{IF\_TH}} + \dfrac{P_{interferer} \cdot B_{IF}}{B_{spread}}}$$

$$= \frac{1}{\dfrac{1}{SNR_{IF\_TH}} + \dfrac{1}{\dfrac{C}{I} \cdot \dfrac{B_{spread}}{B_{IF}}}}$$

with

P_{sign} - the signal power of the desired signal

$P_{Interferer}$ - the signal power of the direct sequence signal

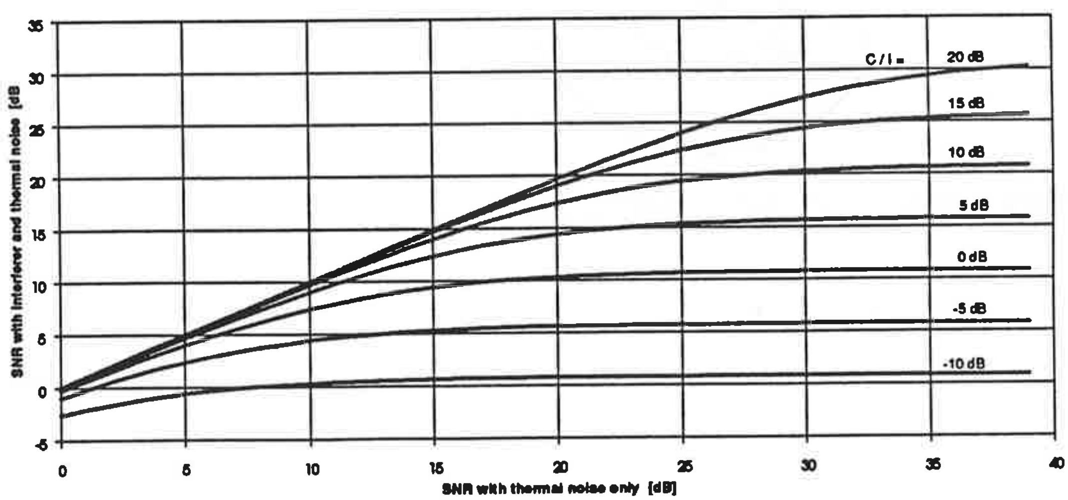
B_{IF} - the IF bandwidth of the frequency hopping receiver

B_{spread} - the RF bandwidth of the direct sequence signal

SNR_{IF_TH} - the signal to noise ratio of the frequency hopping receiver under thermal only conditions

C/I - $P_{sign} / P_{interferer}$

Effective SNR for Frequency Hopping System with Direct Sequence Interferer
Assumes that the RF spectrum of Direct Sequence signal overlaps the RF spectrum of the Frequency Hopping signal, Bspread_DS / BIf_FH = 12



The main conclusion is that the desired signal i.e. the Frequency Hopping RF signal power has to be at least 5 to 10 dB stronger than the Direct Sequence RF signal power for reliable demodulation. This again assumes that demodulation with a BER of 10^{-5} requires an SNR of 15 dB or higher.

3. PRESENT 802.11 RF PHY PROPOSALS

We first look at collocated single DS and FH systems that use the proposed PHYs. The DS signal occupies a constant 22 MHz. The FH signal has an instantaneous bandwidth of 1 MHz and hops over the full 82 MHz. In this case the signals are on the average occupying the same spectrum 22 / 82 * 100 = 27 % of the time. For all the receivers that have a C/I lower than 5 dB communication is possible only if the other net is not active.

When the collocated systems are 3 DS and one FH, **the FH system will be interfered with in all** frequency slots, i.e. at any time the DS system is transmitting.

When the collocated systems are one DS and 3 FH, **the DS system will be interfered with almost 100 %** when the FH system is transmitting.

Clearly, the standard is expected to be successful, in other words, many cells are expected to be in very close proximity and the above scenarios are expected to occur frequently if both standards are approved.

The expected C/I ratios as function of overlapping regions have not been addressed here. In general, when we assume the **same** transmitter power throughout the systems, and simplifying the rather haphazard indoor attenuation patterns, the distance from the receiver to the desired transmitter has to be "5 to 10 dB shorter" than the distance from the receiver to the interfering signal. A more detailed comparison may be provided in a later submission.

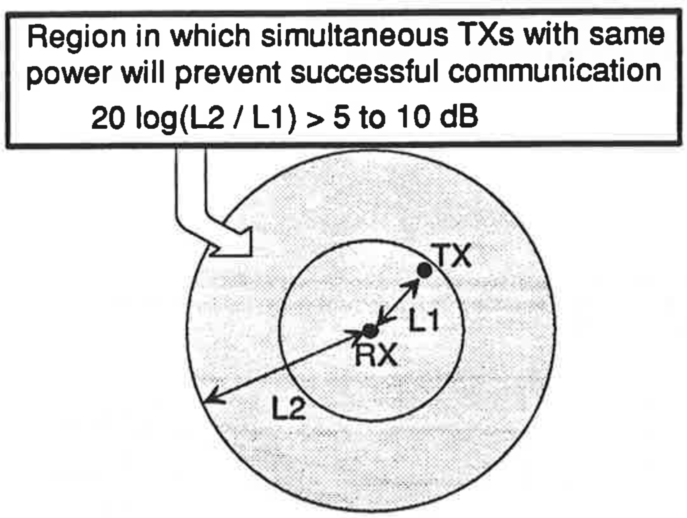


Figure 3. Illustration showing interference region