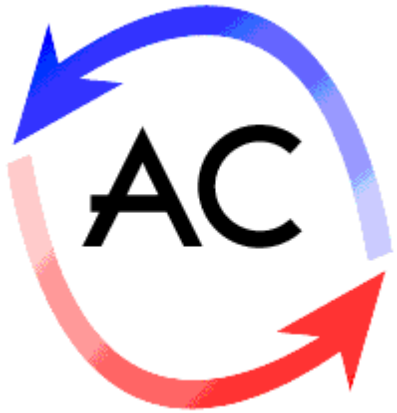
IEEE P802.11
Wireless LANs

The Definition of Spreading and Coding and Their Relation to Processing Gain



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Abstract

The FCC requirement of 10 dB of processing gain to operate in the 2.4 Ghz band is addressed. It is shown how processing gain as defined by the FCC, may be expressed as the sum of three terms, namely, the coding gain, the rate gain, and a waveform spreading gain. The processing gain by this definition is calculated for several proposals for a high rate PHY in the 2.4 Ghz band.

Processing gain is defined as the difference between the SNR (Es/No) required to achieve a threshold BER or PER with a base modulation scheme and the SNR (Es/No) required to achieve the same threshold BER or PER when the signal is ***processed***.

Processing of the signal includes error control coding and spreading of the signal.

Coding gain (See 802.11 document 98/24) is measured on an Eb/No scale rather than an Es/No scale. This prevents the apparent increase in performance that has been gained as a tradeoff between Es/No and rate.

The Barker sequence of the low-rate PHYs provides no ***coding gain***, but it does provide ***a rate gain or spreading gain*** of 13.4 dB and 10.4 dB
respectively for 1 Mbps and 2 Mbps.

In “Towards an Information Theory of Spread-Spectrum Systems”, *Code Division Multiple Access Communications* (Eds. S. G. Glisic and P.A. Leppanen), 1995, James L. Massey it is shown that there is a threshold at which spread spectrum signals begin to significantly lose the ability at achieve an infomation rate close to the full capacity of the channel.

The low rate DS PHYs operate below this threshold, i.e. the spreading in these systems does not signifiantly reduce the channel capacity.

At the rates proposed in the high rate PHY, significant spreading would severely reduce channel capacity.

There is a third type of gain in the Alantro Communications proposal (as well as the low rate PHYs and several other proposals) that is related to the ***bandwidth expansion factor***.

With ***ideal pulse shaping***, the Alantro Communications proposal which operates at 11 Msps, would occupy 11 Mhz of bandwidth.

However, the signal is ***spread*** to a bandwidth of 30 Mhz.

This yields a ***waveform spreading gain*** of 10 log(30/11)=4.36 dB.

Processing Gain =

Coding Gain +

Rate/Spreading Gain +

Waveform Spreading Gain

Code System	Mod	Data Rate (@11MHz)	Code R	C.G.	W. G.	R.G.	P.G.	
11 Barker	BPSK	1Mbps	1/11	0dB	4.3dB	13.4dB	17.7dB	Low Rate DS
11 Barker	QPSK	2Mbps	2/11	0dB	4.3dB	10.4dB	14.7dB	
(4,1) v=6 BCC	BPSK	2.75Mbps	1/4	5.6dB	4.3dB	9.0dB	18.9dB	Alantro Comm
(4,1) v=6 BCC	QPSK	5.5Mbps	1/2	5.6dB	4.3dB	6.0dB	15.9dB	
(2,1) v=6 BCC	QPSK	11Mbps	1	5.4dB	4.3dB	3.0dB	12.7dB	
(3,2) v=6 BCC	QPSK	14.6Mbps	4/3	5.2dB	4.3dB	1.8dB	11.3dB	
(4,3) v=6 BCC	QPSK	16.5Mbps	3/2	4.5dB	4.3dB	1.2dB	10.0dB	
(5,4) v=6 BCC	QPSK	17.6Mbps	8/5	4.2dB	4.3dB	0.8dB	9.3dB	
(8,7) v=6 BCC	QPSK	19.2Mbps	14/8	4.0dB	4.3dB	0.6dB	8.9dB	
(2,1) v=2 BCC	QPSK	11Mbps	1	3.7dB	4.3dB	3.0dB	11dB	Other BCCs
(2,1) v=4 BCC	QPSK	11Mbps	1	4.7dB	4.3dB	3.0dB	12 dB	
(2,1) v=8 BCC	QPSK	11Mbps	1	6.1dB	4.3dB	3.0dB	13.4 dB	
OPPM	QPSK	8Mbps	8/11	2.2dB	4.3dB	4.4dB	10.9dB	Others PHYs
(8,16,4) MOK	QPSK	11Mbps	1	2.3dB	4.3dB	3.0dB	9.6dB	
(16,32,8) MOK	QPSK	6.9Mbps	5/8	~5.0dB	4.3dB	5.0dB	~14.3dB	

Processing Gain for various systems

The ***jamming margin*** is proportional to the spreading gain/rate gain plus the coding gain. (See *Digital Communications*, *Third Edition*, John G. Proakis, pp. 707-8.)

Code System	Mod	Data Rate (@11MHz)	Code R	Es/No (10^-5)	Eb/No (10^-5)	Adds (per bit)	Cmps (per bit)	
11 Barker	BPSK	1Mbps	1/11	-0.7dB	9.7dB	10	1	Low Rate DS
11 Barker	QPSK	2Mbps	2/11	2.3dB	9.7dB	10	1	
(4,1) v=6 BCC	BPSK	2.75Mbps	1/4	-1.9dB	4.1dB	152	64	Alantro Comm
(4,1) v=6 BCC	QPSK	5.5Mbps	1/2	1.1dB	4.1dB	152	64	
(2,1) v=6 BCC	QPSK	11Mbps	1	4.3dB	4.3dB	132	64	
(3,2) v=6 BCC	QPSK	14.6Mbps	4/3	2.7dB	4.5dB	99	48	
(4,3) v=6 BCC	QPSK	16.5Mbps	3/2	7.0dB	5.2dB	88	42.7	
(5,4) v=6 BCC	QPSK	17.6Mbps	8/5	7.7dB	5.5dB	82.5	40	
(8,7) v=6 BCC	QPSK	19.2Mbps	14/8	5.1dB	5.7dB	75.4	36.6	
(2,1) v=2 BCC	QPSK	11Mbps	1	6.0dB	6.0dB	12	4	Other BCCs
(2,1) v=4 BCC	QPSK	11Mbps	1	5.0dB	5.0dB	36	16	
(2,1) v=8 BCC	QPSK	11Mbps	1	3.6dB	3.6dB	516	256	
OPPM	QPSK	8Mbps	8/11	6.1dB	7.5dB	HIGH	HIGH	Others PHYs
(8,16,4) MOK	QPSK	11Mbps	1	7.4dB	7.4dB	14	3.75	
(16,32,8) MOK	QPSK	6.9Mbps	5/8	~2.6dB	~4.7dB	48	6.2	

AWGN Performance and Complexity of various systems