

## **7 15.247(E) PROCESSING GAIN (FROM PANASONIC)**

**Product Name:** KX-HCM270

### **Limits:**

The processing gain of a direct sequence system shall be at least 10 dB. The processing gain shall be determined from the ratio in dB of the signal-to-noise ratio with the system spreading code turned off to the signal-to-noise ratio with the system spreading code turned on, as measured at the demodulated output of the receiver.

### **Test Equipment:**

MS2602A Spectrum analyzer  
HP ESG D4000A signal generator  
HP437B Power meter  
HP8494A attenuator 1dB steps  
HP8495B attenuator 10dB steps  
PD28-0725-SMA power spiltter  
Laptop Computer Panasonic CF-M1V

### **Theoretical calculation:**

#### **1. THEORETICAL PROCESS GAIN FOR DBPSK & DQPSK**

This value and the measured J/S ratio are used in the following equation to calculate the Process Gain (Gp) of the system.

$$G_p = (S/N)_o + M_j + L_{sys}$$

Where:

- (S/N)<sub>o</sub>: Theoretical signal to noise ratio required to maintain the normal operation just before the BER appears. In real measurements the maximum error of 0.001 is allowed in an ideal system using their modulation scheme with all codes turned off (i.e. no spreading or processing gain).
- M<sub>j</sub>: Maximum jammer to Signal Ratio that recorded at the detected BER.
- L<sub>sys</sub>: System losses such as non-ideal synchronization, tracking circuitry, non-optimal baseband receiver filtering and etc... These losses can be in excess of 3 dB for each transmitter and receiver pair. For the purpose of this processing gain calculation we assume a L<sub>sys</sub> at its minimum value of 2 dB.

Ref.: Dixon, R, Spread Spectrum Systems . (New York: Wiley, 1984), Chapter 1.

- (S/N)<sub>0</sub>: Refer to attached curves, BER versus (S/N)<sub>0</sub> for Differential Coherent Detection of Differentially Encoded BPSK
- Processing gain  $G_p = (S/N)_o + L_{sys} + M_j = (S/N)_o + 2 + M_j$

4.5 Definitions and Performance of Spectral and Power Efficiency

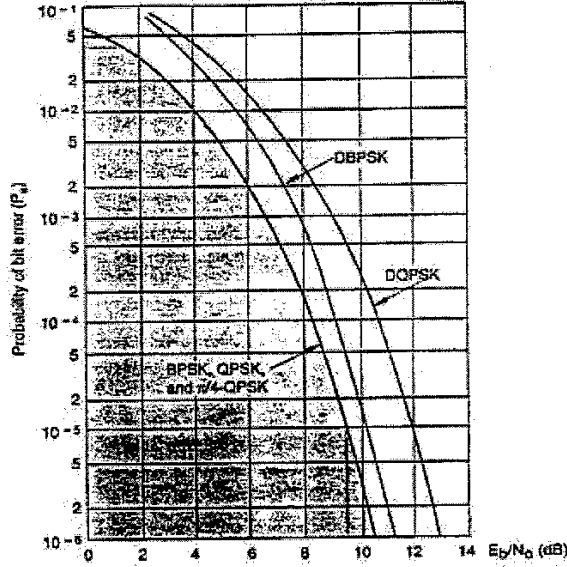


Figure 4.5.1 Theoretical  $P_b = f(E_b/N_0)$  performance in a stationary additive white Gaussian noise (AWGN) environment. Ideal, linearly amplified coherent BPSK, QPSK, and differentially demodulated DBPSK systems are illustrated. The performance of non-linearly amplified P-QPSK and GMSK is compared to ideal linearly amplified QPSK in Figures 4.3.33 and 4.3.34. (From Proakis, 1989.) See Appendix A.3.

ically equivalent term bit-error rate (BER) is used in applied references and specifications.

Power efficiency of modulated systems is defined as being inversely proportional to the

$$BER = f(C/N)$$

and/or

$$BER = f(E_b / N_0)$$

equations and performance curves, where  $E_b$  is the average energy of a modulated bit and  $N_0$  is the noise power spectral density (the noise power in a normalized 1-Hz bandwidth) at the demodulator input. The higher the probability of error, the lower the power efficiency, since transmitted power is "wasted" on more bad data.

## 2. THEORETICAL PROCESS GAIN FOR CCK MODULATION

The Processing gain is related to be jamming margin as follows:

$$G_p = (S/N)_{\text{output}} + (J/S) + L_{\text{system}}$$

Where BER reference is the reference bit error ratio with its corresponding, theoretical output signal to noise ratio per symbol,  $(S/N)_{\text{output}}$ ,  $(J/S)$  is the jamming margin(jamming signal power relative to desired signal power), and  $L_{\text{system}}$  are the system implementation losses..

The maximum allowed total system implementation loss is 2 dB.

The ISL3873 direct sequence spread spectrum baseband processor use CCK modulation which is a form of M-ary Orthogonal Keying. The Probability of error for generalized M-ary orthogonal signaling using coherent demodulation is given by:

$$P_e = 1 - P_{c1} = 1 - \frac{1}{\sqrt{2p}} \int_{\frac{S_{01}}{N_0}}^{\infty} \left[ 2(1 - Q\left\{z + \sqrt{2 \frac{E_b}{h}}\right\}) \right]^{\frac{M-1}{2}} \exp\left\{-\frac{z^2}{2}\right\} dz$$

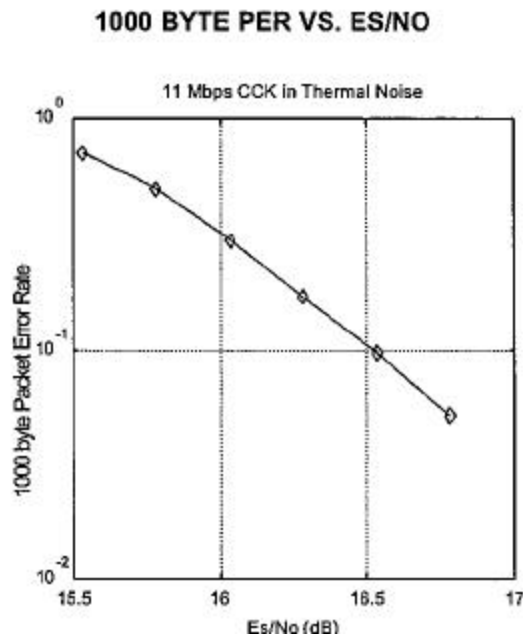


figure.1 1000 byte PER vs. Es/No

Therefore

$$G_p = \left( \frac{E_s}{N_o} \right)_{output} + \left( \frac{J}{S} \right) + L_{system} = 16.4dB + 2.0dB + \left( \frac{J}{S} \right) \geq 10dB$$

$$G_p = 18.4dB + \left( \frac{J}{S} \right) \geq 10dB$$

The minimum jammer to signal ratio is as follows:

$$\left( \frac{J}{S} \right) \geq -8.4dB$$

For the case of the ISL3873, the bit rates are 1, 2, 5.5, and 11 Mbps. The corresponding symbol rates are 1, 1, 1.375, and 1.375 MSps. The chip rate is always 11 MCps, so the ratio of chip rate to symbol rate is 11:1 for the 1 and 2 Mbps rates and 8:1 for the 5.5 and 11 Mbps rates. Since the symbol rate to bit rate is less than 10 for the higher rates, we supply the theoretical processing gain calculation for these cases where spread spectrum processing gain with embedded coding gain is utilized. This is reasonable in that they cannot be separated in the demodulation process. If a separable FEC coding scheme were used, we would not be comfortable making this assertion.

As can be seen from the curve of figure 1, the Es/N0 is 16.4 dB at the PER of 8%. This PER can be related to a BER of 1e-5 on 1000 byte packets. With 8 bits per symbol, the Eb/N0 is then 7.4 dB or 9 dB less than the Es/N0. It is well known that the Eb/N0 of BPSK is 9.6 dB for 1e-5 BER, so therefore the coding gain of CCK over BPSK is 2.2 dB. We add this to the processing gain of 9 dB to get 11.2 dB overall processing gain for the CW jammer test.

Taking the calculations above, if the  $\left( \frac{J}{S} \right) \geq -8.4dB$  then the equipment passes the CW jamming test.

### Test Procedures:

Obtain the simplex link shown. Perform all independent instrumentation calibrations prior to this procedure. Set operating power levels using fixed and variable attenuators in system to meet the following objectives:

1. Signal Power at receiver approximately -60 dBm (above thermal sensitivity such that thermal noise does not cause bit errors).
2. Signal Power at power meter between -20 and -30 dBm for optimal linearity.
3. Use spectrum analyzer to monitor test.
4. Ensure that CW Jammer generator RF output is disabled and measure the power at the power meter port using the power meter. This is the relative signal power,  $s_r$ .

5. Disable Transmitter, and set CW Jammer generator RF output frequency equal to the carrier frequency and enable generator output. Set reference CW Jammer power level at power meter port 8.4 dB below  $s_r$  (minimum J/S, or 10 dB processing gain reference level). Note the power level setting on the generator, this is the reference CW Jammer power setting,  $\mu$ .
6. Disable CW Jammer, re-establish link. PER test should be operating essentially error-free.
7. Enable CW Jammer at the reference power level and verify that the PER test indicates a PER of less than 8%.
8. Alternatively, adjust the CW Jammer level to that which causes 8% PER and verify that the S/J is less than 8.4 dB.
9. Repeat step 7 for uniform steps in frequency increments of 50 kHz across the receiver passband with the CW Jammer. In this case the receiver passband is +8.5 MHz.

The number of points where the PER fails to achieve 8% (is higher than 8%) is determined and if this is above 20% of the total, the test is failed otherwise it is passed.

The margin by which the radio passes the test (for informational purposes) can be determined from the average of the remaining points' PERs scaled on the PER curve above.

The numerical data associated with the following radio channels is tabulated and presented for

Channel 1: 2412 MHz (low channel of the band)

Channel 6: 2437 MHz (middle channel of the band)

Channel 11: 2462 MHz (high channel of the band)

**Test setup:** as shown at next page

**Test Data:**

**Processing gain test result summary**

Channel Frequency	Data rate(Mbps)	Worst point of the 8% FER (Limit is 20%)	Result
<b>1ch : 2412MHz</b>	<b>1</b>	<b>13.1</b>	<b>Passed</b>
<b>1ch : 2412MHz</b>	<b>2</b>	<b>13.4</b>	<b>Passed</b>
<b>1ch : 2412MHz</b>	<b>5.5</b>	<b>13.3</b>	<b>Passed</b>
<b>1ch : 2412MHz</b>	<b>11</b>	<b>13.2</b>	<b>Passed</b>
<b>6ch : 2437MHz</b>	<b>1</b>	<b>12.8</b>	<b>Passed</b>
<b>6ch : 2437MHz</b>	<b>2</b>	<b>13.8</b>	<b>Passed</b>
<b>6ch : 2437MHz</b>	<b>5.5</b>	<b>13.4</b>	<b>Passed</b>
<b>6ch : 2437MHz</b>	<b>11</b>	<b>12.8</b>	<b>Passed</b>
<b>11h : 2462MHz</b>	<b>1</b>	<b>12.6</b>	<b>Passed</b>
<b>11h : 2462MHz</b>	<b>2</b>	<b>13.6</b>	<b>Passed</b>
<b>11h : 2462MHz</b>	<b>5.5</b>	<b>13.4</b>	<b>Passed</b>
<b>11h : 2462MHz</b>	<b>11</b>	<b>13.6</b>	<b>Passed</b>