UtiliCom
SPREAD SPECTRUM COMMUNICATIONS

323 Love Place, Goleta, CA 93117 Phone: (805) 964-5848 FAX: (805) 964-5706

LongRanger 2050 Processing Gain

Measurements and Calculations

The LongRanger 2050 runs at a fixed chip rate of 9.216 Mchip/sec. The spreading code lengths can be programmed to 11, 15, 31 and 63 chips, and the modulation can be set to BPSK or QPSK. The final user data rates for these various combinations are listed in the table below:

Code length	Symbol Rate	Modulation	Data rate	Theoretical Process Gain
63	146 K	BPSK	146 Kbps	18 dB
31	297 K	BPSK	297 Kbps	15 dB
15	614 K	BPSK	614 Kbps	11.8 dB
11	837 K	BPSK	837 Kbps	10.4 dB
15	614 K	QPSK	1.23 Mbps	11.8 dB
11	837 K	QPSK	1.67 Mbps	10.4 dB

The processing gain was measured at the highest user data rate setting (11 chips, QPSK), since this corresponds to the lowest theoretical processing gain.

Test Setup and Calibration

The processing gain measurement was performed using the CW jamming method. Figure 1 illustrates the test setup used for the test. The levels of the CW jammer and the spread spectrum transmitter were initially calibrated for equal power at the receiver (-56 dBm) by measuring the two signals using a power meter equipped with an HP8481A thermoelectric power sensor. The setting of the HP394A attenuator that resulted in equal power at the receiver was noted.

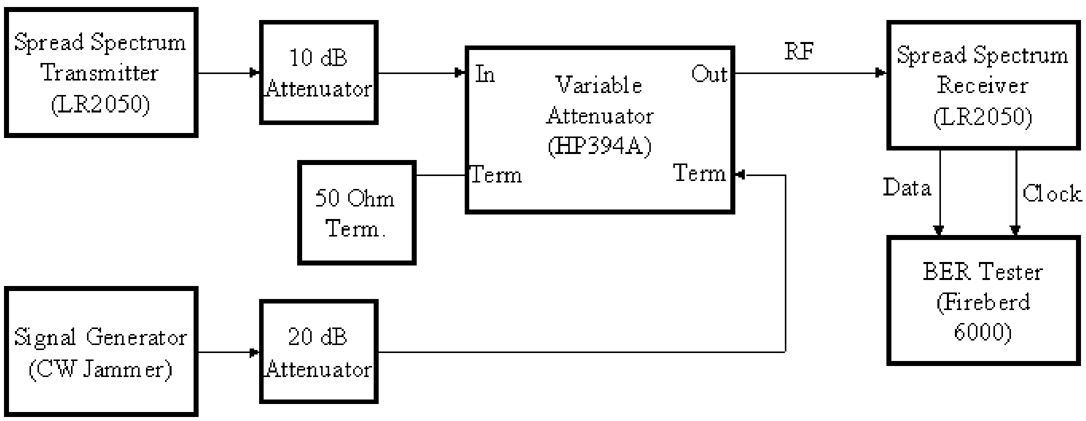

Figure 1. Processing Gain Test Set Up

Test Procedure

The level of the CW jammer input to the receiver was held constant throughout the test. The frequency of the jammer was stepped through the passband of the receiver channel (10 MHz) in 100 KHz steps. At each frequency step of the jammer, the signal from the transmitter was adjusted (by turning the HP394A attenuator), to degrade the Bit Error Rate (BER) to 5×10^{-5} (0.00005). The delta of the attenuator setting from the point of equal power was noted and is presented in Figure 2 as the S/J. The actual data points are also attached.

Once all the data points were gathered, an unweighted average of the S/J measurements over a 9.216 MHz passband (the central 50% of the spread spectrum main lobe) was calculated. This average value is 0.88 dB

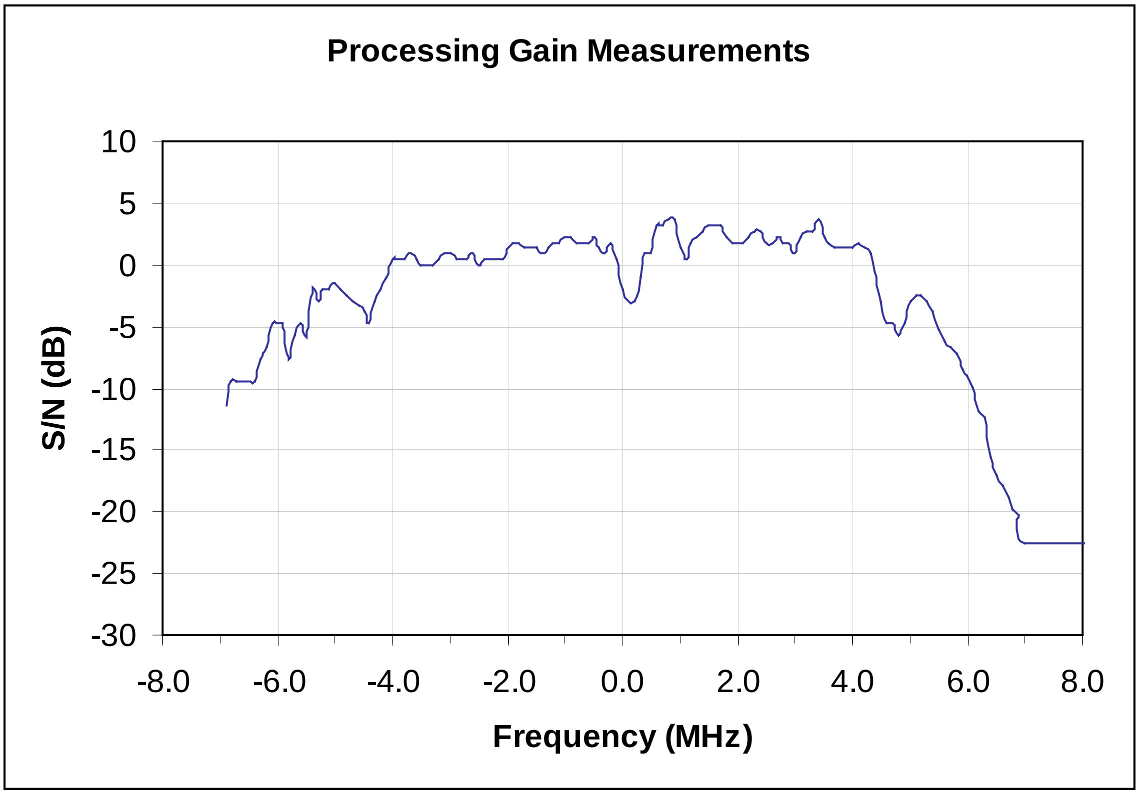

Figure 2. S/N versus frequency for a BER of 0.5×10^{-5}

Processing Gain Calculations

The processing gain (Gp) was calculated using the formula:

Gp = (S/N)o + Mj + Lsys (Equation 1)

where: (S/N)o = Signal to Noise Ratio
Mj = J/S ratio
Lsys = system losses

Ref.: Dixon, R. *Spread Spectrum Systems* 2nd ed. (New York, John Wiley and Sons, 1984), chapter 1

For DQPSK modulation, the probability of error as a function of the signal to noise ratio is a complex equation. This equation is derived in Proakis "Digital Communications", 3rd edition. (Boston, McGraw-Hill, 1995), page 277. Figure 4-2-20, taken from that book (next page), shows the plot of this function.

From this plot we find that a probability of error of 5×10^{-5}, requires a signal to noise ratio of 11.2 dB for DQPSK.

The processing gain for the LongRanger 2050 was then calculated, using equation 1 and considering no system losses:

$$G_p = (S/N)_o + M_j + L_{sys}$$
$$G_p = 11.2\text{ dB} - 0.88\text{ dB} + 0$$

This yields an average processing gain of 10.32dB.

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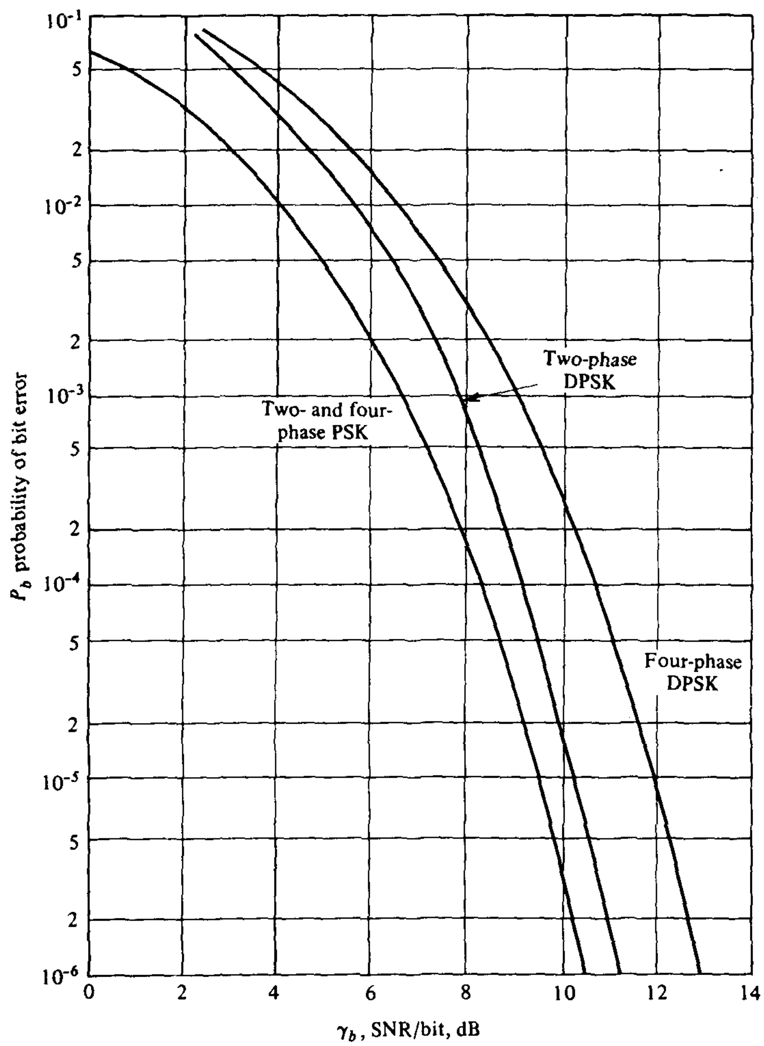

FIGURE 4.2.20
Probability of bit error for binary and four-phase PSK and DPSK.