Theoretical BER for Common Modulations

GDP Space Systems' customers frequently ask "What is the theoretical Bit Error Rate?" for various types of modulation. So, we have reviewed and analyzed the literature to find what we believe are the performance curves a receiver's performance should be compared to. Our answers are shown in the table and figure below and described in the following.

The results assume a perfect signal in Additive White Gaussian Noise (AWGN). For the AWGN channel, there are only a few quantities that need to be computed to calculate the Bit Error Rate (BER): the Energy per Bit divided by the Noise Density, EbNo, and the Normalized Squared Euclidean Distance (NSED) between the symbols of the modulation. The EbNo and NSED are used to calculate the pairwise error probability, which in AWGN, is the upper-tail probability of the standard normal distribution. When a closed form solution for the NSED is not realizable, the union bound technique is used to derive the BER. The union bound is dominated by the term(s) with the smallest NSED distance(s). As a result, the union bound can be truncated to the first few terms. The number of terms is chosen so the BER calculation is within tenths of a dB of the simulated theoretical results of the Maximum Likelihood Sequence Detector (MLSD). The table and figure below provide the results. The modulations labeled with MSLD are for ARTM trellis type demodulation. The F&S and I&D labels are for classic Filter and Sample and Integrate and Dump, single symbol, type demodulation.

Eb/No in dB	B/Q/OQPSK	PCM/FM MLSD	PCM/FM F&S	SOQPSK MLSD	SOQPSK I&D	Multi-H MLSD
0	7.86E-02	1.08E-01	1.35E-01	7.85E-02	9.61E-02	9.86E-02
1	5.63E-02	6.42E-02	1.08E-01	5.68E-02	7.31E-02	7.46E-02
2	3.75E-02	3.47E-02	8.25E-02	3.86E-02	5.29E-02	5.33E-02
3	2.29E-02	1.67E-02	5.96E-02	2.43E-02	3.62E-02	3.55E-02
4	1.25E-02	7.01E-03	4.02E-02	1.40E-02	2.32E-02	2.17E-02
5	5.95E-03	2.49E-03	2.49E-02	7.20E-03	1.38E-02	1.19E-02
6	2.39E-03	7.20E-04	1.39E-02	3.24E-03	7.47E-03	5.69E-03
7	7.73E-04	1.61E-04	6.78E-03	1.24E-03	3.66E-03	2.32E-03
8	1.91E-04	2.59E-05	2.80E-03	3.87E-04	1.59E-03	7.73E-04
9	3.36E-05	2.72E-06	9.41E-04	9.29E-05	5.95E-04	2.02E-04
10	3.87E-06	1.66E-07	2.44E-04	1.60E-05	1.87E-04	3.93E-05
11	2.61E-07	5.10E-09	4.56E-05	1.82E-06	4.76E-05	5.41E-06
12	9.01E-09	6.53E-11	5.66E-06	1.20E-07	9.21E-06	4.93E-07
13	1.33E-10	2.79E-13	4.19E-07	4.06E-09	1.26E-06	2.73E-08
14	6.81E-13	2.97E-16	1.63E-08	5.86E-11	1.11E-07	8.04E-10
15	9.12E-16	5.55E-20	2.79E-10	2.90E-13	5.53E-09	1.05E-11

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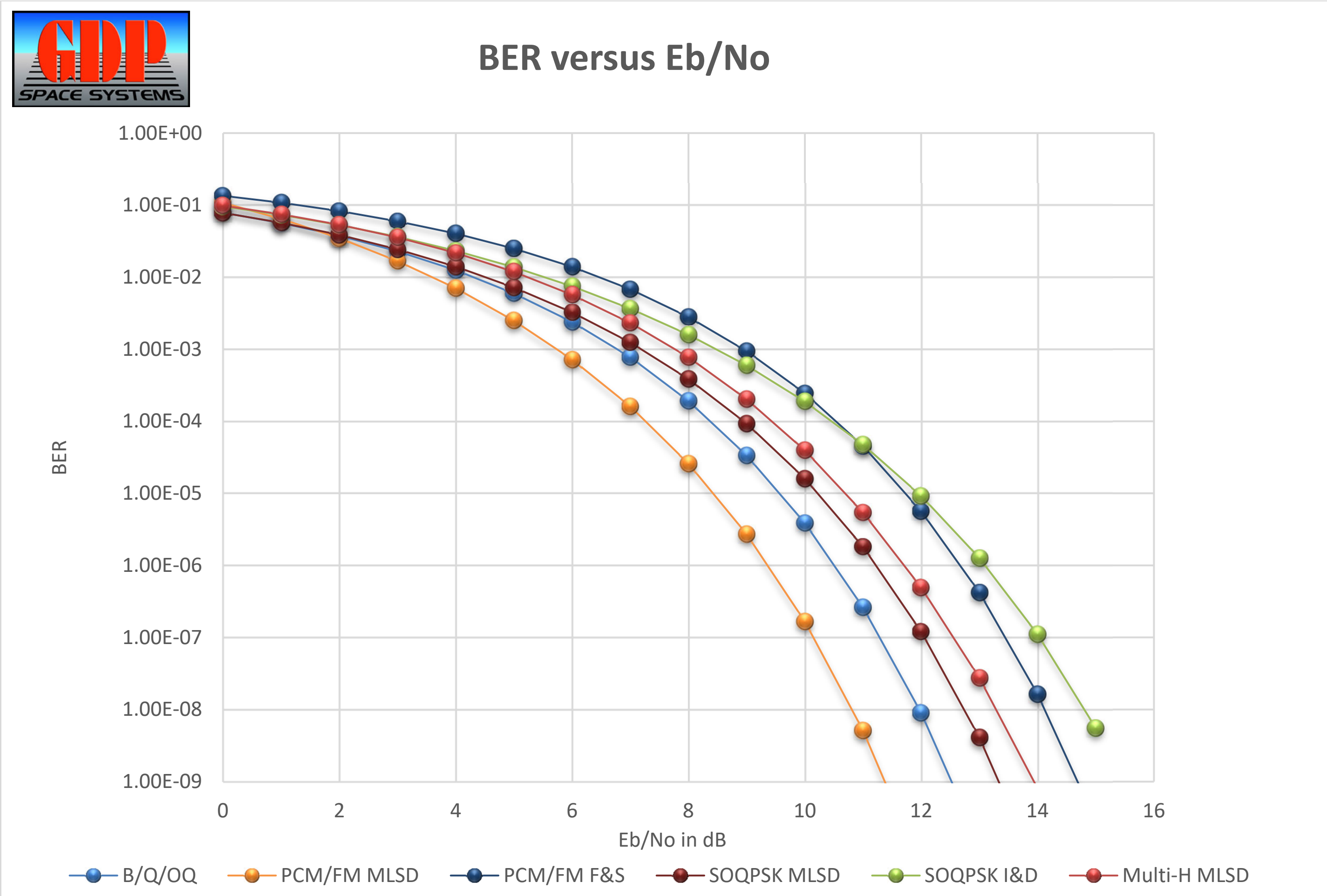

Theoretical BER Curves for Common Modulations

For large EbNo the following asymptotic performance relationships apply.

PCM/FM MSLD ~ 1.1dB better than B/Q/OQPSK.

PCM/FM MSLD ~ 3.3dB better than PCM/FM F&S.

SOQPSK MSLD ~ 2.5dB better that SOQPSK I&D.

PCM/FM MSLD ~ 2.0dB better than SOQPSK MSLD.

SOQPSK MSLD ~ 0.9dB better that Multi-H MSLD.

Note the above BER performance is for data without differential encoding and without randomization. Differential encoding/decoding doubles the BER (IRIG 106 specifies the use of differential encoding/decoding for SOQPSK without LDPC) and IRIG self-synchronizing 15-bit randomization/derandomization triples the BER.