Theoretical BER curves for the IEEE 1 and 2 Mbps modulations

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The expected BER versus Eb/N0 curves for these cases may be determined as follows.

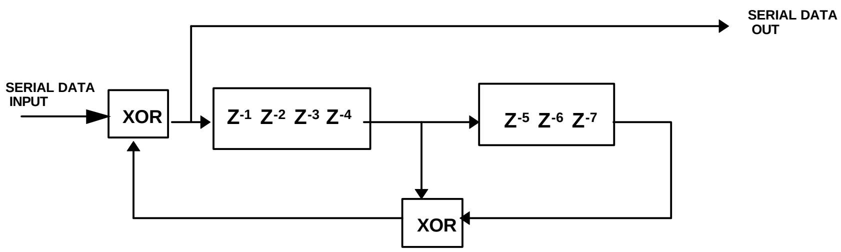
Differential error extension.

The modulation is either DBPSK or DQPSK for 1 and 2 Mbps. With differential coding, there is an error extension factor of 2 which comes from the fact that if one symbol is in error, then the next will be demodulated in error too since it's phase is dependent on the change of phase from symbol to symbol. In DBPSK, this results in a simple factor of two in BER. With QDQPSK, the picture is a little muddied in that a symbol error may cause one or two bit errors since two bits are carried per symbol. The IEEE 802.11 modulations use Grey coding of the phase so that usually only one bit error occurs with a symbol error. Sometimes, two bit errors occur, but this is infrequent at the BER considered. The bit error pattern can be adjacent, separated by one or separated by two for the two error case. This will be shown to be important in descrambling.

De-Scrambling Error Extension

The IEEE 802.11 modulation is scrambled with a self synchronizing scrambler. This scrambler implements a polynomial multiply operation using a feed back shift register configuration as shown in figure 1.

Scrambler Polynomial; $G(z)=Z^{-7} + Z^{-4} + 1$



It mixes two taps out of a 7 bit shift register with the data stream. The shift register is fed the received data and any error will propagate through the register for the next 7 clocks. As the error bit passes each of the taps, it will contaminate the output data. Thus each input error can produce several errors on the output. The bit error rate has to be adjusted to account for this effect. For the IEEE 802.11 modulation, taps at registers 4 and 7 are used. In BPSK mode, this produces an error extension of 3. Thus, for an output rate of 10^{-5}, the input rate must be $0.33 * 10^{-6}$ which requires that the Eb/N0 be increased by 0.5 dB. In QPSK mode, the errors can be non adjacent since they are symbol errors and the bit in error can be either the first or second of the dibits. This makes it possible for some errors to cancel in the de-scrambler. Therefore the error extension can be either 2 or 3 in this case.

What we see when running the BER test is that the errors generally occur in groups of 6 with occasional 4s.

The overall effect is to move where we operate on the BER curve. The curve below shows the resulting BER versus Eb/N0 curve. It is well known that a simple BPSK link operates at 9.6 dB for 1e-5 BER. With the error extension effect, we see that at that Eb/N0, the error rate is 6 e-5. Or, conversely, we must operate at 10.3 dB to get 1e-5.

When operating DQPSK at 2 Mbps, the Eb/N0 remains essentially the same, but the Es/N0 goes up by 3 dB. For the purposes of the FCC testing for CW jamming, we add the allowed 2 dB for implementation loss to get a net Es/N0 of 15.3 dB.