Noise, S/N and E_b/N_o

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E_b/N_o

- E_b/N_o is defined as the *normalized* signal to noise ratio, or signal to noise per bit.
- E_b/N_o is particularly useful when comparing the comparing the Bit error rate (BER) performance of different modulation schemes.

E_b/N_0 is equal to the SNR divided by the "gross" link spectral efficiency in (bit/s)/Hz, where the bits in this context are transmitted data bits, inclusive of error correction information and other protocol overhead.

$$\frac{S}{N} = \frac{E_b}{N_0}\frac{f_b}{B}$$

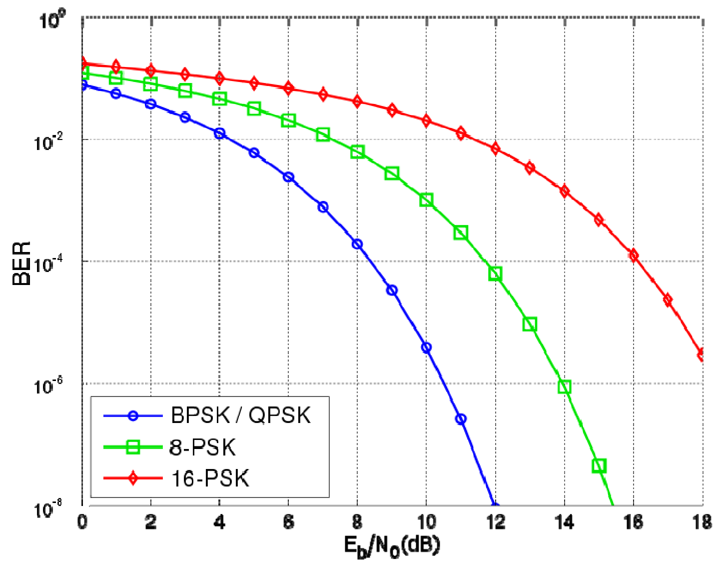
B = channel bandwidth, f_b = channel data rate

E_b/N_o and E_s/N_o

- E_s = energy per symbol (one symbol may represent multiple bits)

$$\frac{E_S}{N_0} = \frac{E_B}{N_0}\log_2 M$$

M= number of alternative modulation symbols



Noise density and Noise power

- N_o = noise density, watts/Hz
- $P_n = N_oB$ = noise power, where B = bandwidth (Hz)
- For thermal (white noise): $N_o = kT$, k = Boltzman's constant (k = 1.38 x 10 $^{-23}$ joules/kelvin) and T=290K for room temperature.
- Johnson–Nyquist noise (thermal noise, Johnson noise, or Nyquist noise) is
  the electronic noise generated by the thermal agitation of the charge carriers (usually the electrons) inside an electrical conductor at equilibrium

Thermal Noise in dBm

$$P_n = kTB \times 1000 \quad \text{milliWatts}$$

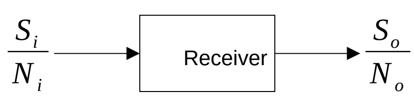
$$P_{n\,dBm} = 10\log_{10}(kTB1000)$$

$$P_{n\,dBm} = -174 + \log_{10} B$$

Noise Figure -Noise power in excess of kT-

• KT is the lower limit of the noise density. All solid state electronics have additional noise.

• Communication receivers often specify the Noise Figure NF as a performance metric. It indicates how much noise the receiver electronics add to the thermal noise.



$$\text{Noise Factor: } \quad F \equiv \frac{\frac{S_i}{N_i}}{\frac{S_o}{N_o}} \qquad 1 \le F < \infty$$

$$\text{Noise Figure: } \quad NF \equiv 10\log_{10} F \qquad 0 \le NF < \infty$$

Total Noise in dBm

$$P_n = kTBF \times 1000 \quad \text{milliWatts}$$

$$P_{n\,dBm} = 10\log_{10}(kTBF\,1000)$$

$$P_{n\,dBm} = -174 + \log_{10} B + NF$$

Some Typical Noise Figures		
Noise Figure-NF	**Noise Factor-F**	**Device**
1dB	1.26	Satellite Receiver
5dB	3.16	Cell Phone
8dB	6.31	Wi-Fi
25dB	316	Spectrum Analyzer

Bandwidth (B)	Thermal noise power	Notes
1 Hz	−174 dBm	
10 Hz	−164 dBm	
100 Hz	−154 dBm	
1 kHz	−144 dBm	
10 kHz	−134 dBm	FM channel of 2-way radio
100 kHz	−124 dBm	
180 kHz	−121.45 dBm	One LTE resource block
200 kHz	−120.98 dBm	One GSM channel (ARFCN)
1 MHz	−114 dBm	
2 MHz	−111 dBm	Commercial GPS channel
6 MHz	−106 dBm	Analog television channel
20 MHz	−101 dBm	WLAN 802.11 channel