Chapter 4

Problem 4.1

With the given formula $N = kT_K B_M$ and given values on temperature and bandwidth we get (Boltzmann's constant is $k = 1.38 \times 10^{-23}$ W/Hz/K)

$$N = \boxed{4 \times 10^{-15} \text{ W} = -144 \text{ dBW} = -114 \text{ dBm}}$$

as the observed noise power over the resistor.

Problem 4.4

Relations between polar and quadratic forms of baseband signals are

$$I(t) = A(t)\cos\phi(t)$$
$$Q(t) = A(t)\sin\phi(t)$$

and

$$A(t) = \sqrt{I^2(t) + Q^2(t)}$$
$$\phi(t) = \arctan\left(\frac{Q(t)}{I(t)}\right)$$

Hint: Use the trigonometric identity $A\cos(\alpha+\beta) = A\cos\alpha\cos\beta - A\sin\alpha\sin\beta$.

Problem 4.5

Standard AM carrying the information signal $g(t)$ on the radio signal as $s(t) = A[1 + g(t)]\cos 2\pi f_0 t$.

(a) With a single sinusoid $g(t) = \frac{1}{2}\cos 2\pi 500t$ the power in the side-bands is 8 times lower than the carrier signal power, giving

$$\text{Efficiency} = \frac{\text{Power in sidebands}}{\text{Total power}} = \boxed{\frac{1}{9}}$$

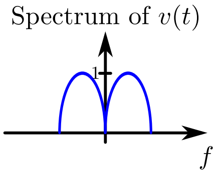
(b) With two sinusoids in $g(t) = \frac{1}{2}\cos 2\pi 500t + \frac{1}{2}\cos 2\pi 700t$ and the same amplitude on each as in (a), the power in the side-bands is now doubled compared to (a) and 4 times lower than the carrier signal power, giving

$$\text{Efficiency} = \frac{\text{Power in sidebands}}{\text{Total power}} = \boxed{\frac{1}{5}}$$

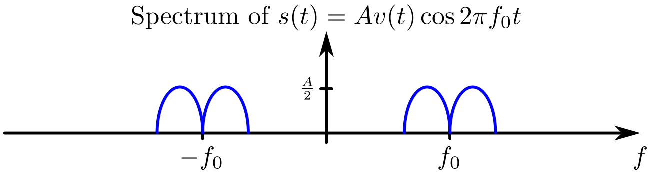
Problem 4.7

Let's start with the DSB signal, where $v(t)$ is chosen arbitrarily:

Spectrum of $v(t)$

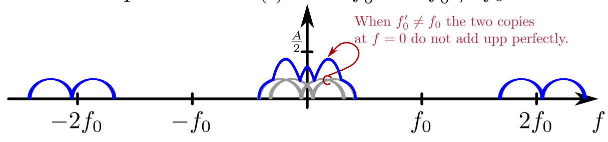


Spectrum of $s(t) = Av(t)\cos 2\pi f_0 t$



(a) When down-converting with a frequency f_0', close to f_0, we get

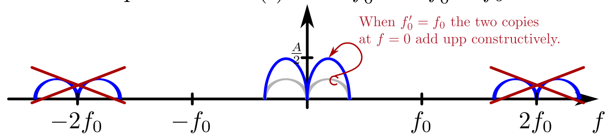
Spectrum of $s(t)\cos 2\pi f_0' t$ for $f_0' \neq f_0$



The two copies of the signal at the center "almost" lign up to form a scaled version of the signal we started with, $v(t)$.

(b) To complete the detector, we need to do two things: i) make sure that f_0' equals f_0 and ii) remove (filter away) the high-frequency components of the signal:

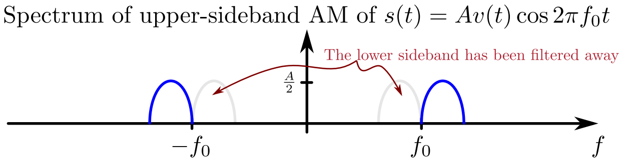
Spectrum of $s(t)\cos 2\pi f_0' t$ for $f_0' = f_0$



To completely reconstruct $v(t)$ we would also need to adjust it's amplitude, so that it becomes equal to what we started with, i.e., we would need to amplify by $2/A$. This is, however, not typical since a radio transmission has an additional unknown propagation loss which we also need to compensate for. This has not been accounted for in this problem.

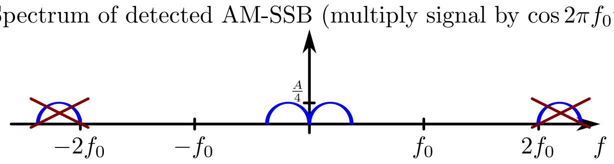
(c) With single-sideband AM, i.e. AM-SSB, only one of the sidebands are transmitted (either the part above or below the carrier frequency). If the part above is used, the transmitted signal looks like:

Spectrum of upper-sideband AM of $s(t) = Av(t)\cos 2\pi f_0 t$



Like with AM-DSB we multiply by $\cos 2\pi f_0 t$ to detect the signal:

Spectrum of detected AM-SSB (multiply signal by $\cos 2\pi f_0 t$)



The baseband signal $v(t)$ is then reconstructed around $f = 0$ and there are two copies above/below $\pm 2f_0$ that we need to filter away. (Again, the amplitude is not correct, and needs to be "corrected" if we want to make a perfect reconstruction of $v(t)$.)

Problem 4.8

We have an input SNR of $(S/N)_{\text{in}} = 30 \text{ dB} = 10^3$ times and a required output SNR of $(S/N)_{\text{out}} = 60 \text{ dB} = 10^6$ times after our FM detector.

(a) We need to achieve a thousand-fold (30 dB) gain in the FM detection, from 30 dB to 60 dB. Using expression (4.25) in the book we see that we need

$$\frac{\Delta f}{f_m} \approx \boxed{26}$$

(b) The bandwidth of our FM signal is given by Carson's rule, which gives

$$W_{\text{RF}} \approx \boxed{54 \text{ kHz.}}$$

Hint: Use the result from (a).