Andre Winkel, Russell Yang October 16, 2025

Lab 1

EE115, Introduction to Communication Systems, Fall 2025

Problem 1: Examining a random signal and AM power efficiency

In this problem, we will examine the average power of a random signal that has its minimum value larger than or equal to -1, and also examine its impact on the power efficiency of conventional amplitude modulation (AM) signals.

a) We begin by using the Gaussian-random-number generator to generate a random sequence

$$m[1], m[2], \ldots, m[N]$$

where we will set N as 200 [a large integer]. We can do so in MATLAB by employing the `randn` function.

b) We can then use the `min` function in order to determine the minimum value of our sequence, which we can denote by $-M_0$. Verbatim, `m_nk = 1/M_0 * m_k; min(m_nk);`.

c) We can then compute the normalized sequence

$$m_n[k] = \frac{1}{M_0} m[k], \tag{1}$$

where its minimum value is found to be

$$m_n[k] = -1.$$

d) We can then compute the average power with

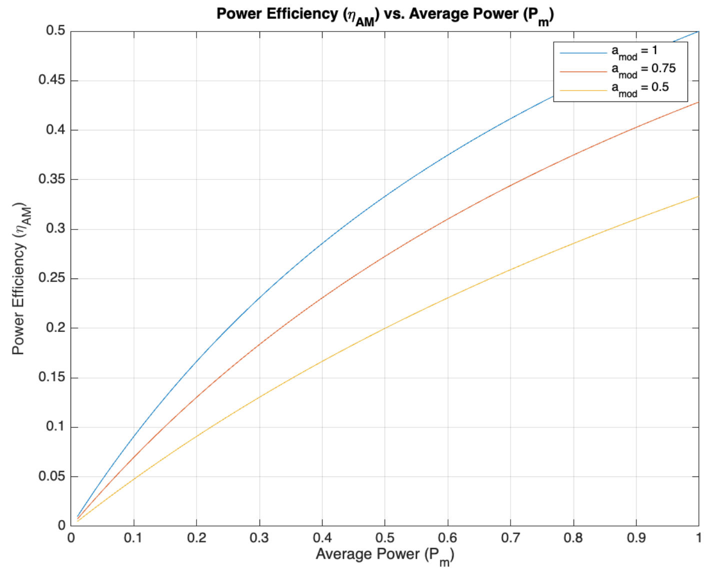
$$P_m = \frac{1}{M} \sum_{k=1}^{N} m_n^2[k]. \tag{2}$$

In MATLAB, this is achieved with `P_m = (1/N) * sum(m_nk.^2)`.

e) Considering the power efficiency of the AM signal, we can determine its power efficiency through

$$\eta_{AM} = \frac{a_{mod} P_m}{1 + a_{mod} P_m}. \tag{3}$$

We can plot η_{AM} versus P_m subject to $0 < P_m < 1$ for each of $a_{mod} = 1, 0.75, 0.5$ in MATLAB, where we observe the following plot:



f) Selecting some values of a random run of the MATLAB program thus frar, we observe η_{AM} for each of $a_{mod} = 1, 0.75, 0.5$ using the same P_m as before. An example run allows us to obtain the values

$$\eta_{AM} = 0.1682 : a_{mod} = 1$$

$$\eta_{AM} = 0.1317 : a_{mod} = 0.75$$

$$\eta_{AM} = 0.0918 : a_{mod} = 0.5$$

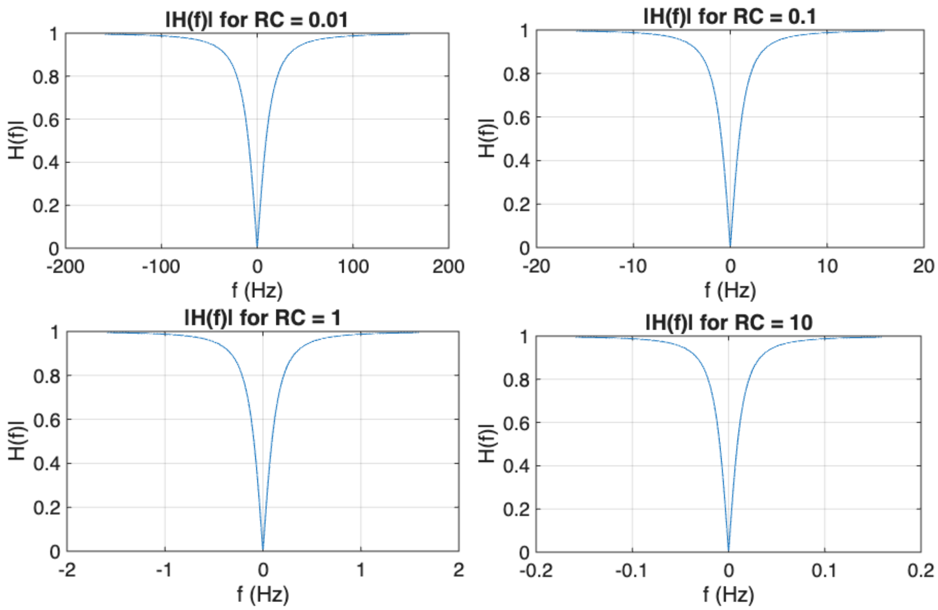
where it becomes evident, once interpreting the respective η_{AM} values as percentages, that conventional amplitude modulation is a very power-inefficient method of transmission.

Problem 2: Examining the quality of a simple DC blocker

In this problem, we will examine the quality of a simple DC blocker which consists of a capacitor C and a resistor R in series. We are given the frequency response of the DC blocker,

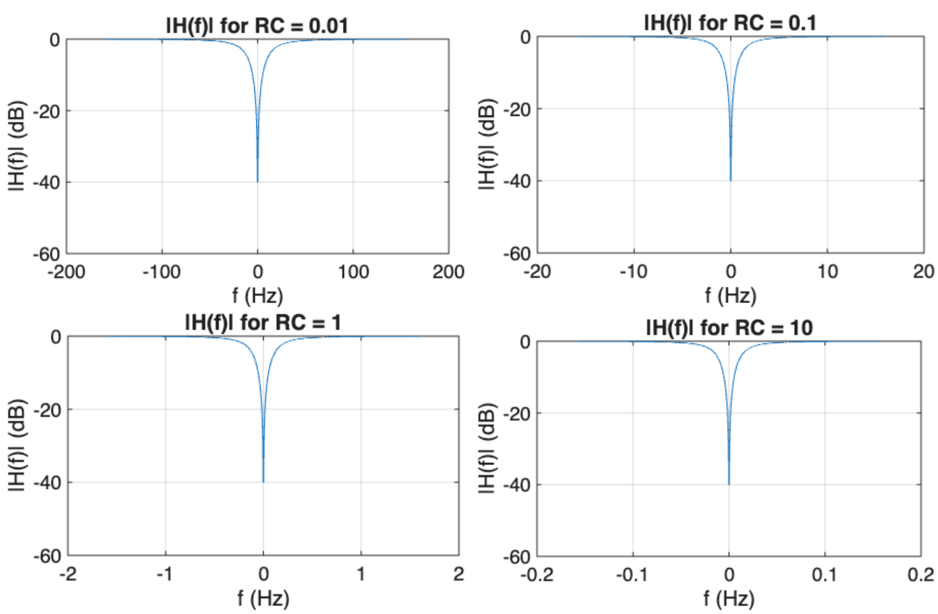
$$H(f) = \frac{R}{R + \frac{1}{j2\pi C}} = \frac{j2\pi f}{j2\pi f + \frac{1}{RC}}. \tag{4}$$

a) Plotting $|H(f)|$ versus f for $|f| < B$ for each of $RC = 0.01, 0.1, 1, 10$, we observe the following plots:



Here, we chose B such that $B = \frac{10}{2\pi RC}$ for each of the respective RC values. This is an appropriate choice, as it allows us to observe the behavior of $|H(f)|$ as it approaches its asymptotic value of 1. We are also able to observe the stopband behavior of the DC blocker as f approaches 0, and everything in between.

b) We can then repeat the above but plotting $20\log_{10}|H(f)|$ versus f. Additionally, we set the vertical range to be from -60dB to 0dB. We observe the following plots:



and we observe that MATLAB dictates our filter to bottom out at -40dB. We also know that the ideal filter will have a gain of $-\infty$dB at $f = 0$.

c) Considering our transfer function $H(f)$ and the requirement $0.95 <= |H(f = 20\text{Hz}) <=$

1, we can find that

$$\mathrm{RC}_{\min} = \sqrt{\frac{(\mathrm{gain}_{\min} = 0.95)^2}{(2\pi f)^2 \cdot (1 - (\mathrm{gain}_{\min} = 0.95)^2)}}.$$

Using MATLAB to solve, we determine

$$\mathrm{RC}_{\min} \approx 0.0242.$$

Code

```
% Problem 1
close all;

% random number
N = 200;
m_k = randn([1,N]);

% min value
M_0 = -(min(m_k))

% normalized sequence
m_nk = 1/M_0 * m_k;
min(m_nk)

% average power
P_m = (1/N) * sum(m_nk.^2)

% power efficiency
Pm_range = linspace(0.01, 1, 100);
a_m = [1, 0.75, 0.5];

eta_100 = (a_m(1) * Pm_range) ./ (1 + a_m(1) * Pm_range);
eta_75 = (a_m(2) * Pm_range) ./ (1 + a_m(2) * Pm_range);
eta_50 = (a_m(3) * Pm_range) ./ (1 + a_m(3) * Pm_range);

figure;
plot(Pm_range, eta_100, 'DisplayName', 'a_{mod} = 1');
hold on;
plot(Pm_range, eta_75, 'DisplayName', 'a_{mod} = 0.75');
plot(Pm_range, eta_50, 'DisplayName', 'a_{mod} = 0.5');
hold off;

title('Power Efficiency (\eta_{AM}) vs. Average Power (P_m)');
xlabel('Average Power (P_m)');
ylabel('Power Efficiency (\eta_{AM})');
legend;
grid on;
```

```
% values
eta_f_100 = (a_m(1) * P_m) / (1 + a_m(1) * P_m) % a_mod = 1
eta_f_75 = (a_m(2) * P_m) / (1 + a_m(2) * P_m) % a_mod = 0.75
eta_f_50 = (a_m(3) * P_m) / (1 + a_m(3) * P_m) % a_mod = 0.5

% Problem 2
% magnitude response
RC = [0.01, 0.1, 1, 10];
for val = RC
    figure;

    B = 10/(2*pi*val);
    f = linspace(-B, B, 1000);
    Hf = (1j*2*pi*f) ./ (1j*2*pi*f + 1/val);

    plot(f, abs(Hf));

    title(['|H(f)| for RC = ', num2str(val)]);
    xlabel('f (Hz)');
    ylabel('H(f)|');
    grid on;
end

% same thing but with 20log10..
for val = RC
    figure;

    B = 10/(2*pi*val);
    f = linspace(-B, B, 1000);
    Hf = (1j*2*pi*f) ./ (1j*2*pi*f + 1/val);

    Hf_dB = 20 * log10(abs(Hf));
    plot(f, Hf_dB);

    ylim([-60 0]);

    title(['|H(f)| for RC = ', num2str(val)]);
    xlabel('f (Hz)');
    ylabel('|H(f)| (dB)');
    grid on;
end

% removing the dc component
f=20;
min_gain=0.95;
RC_min = sqrt(min_gain^2/((2*pi*f)^2*(1-min_gain^2)))
```