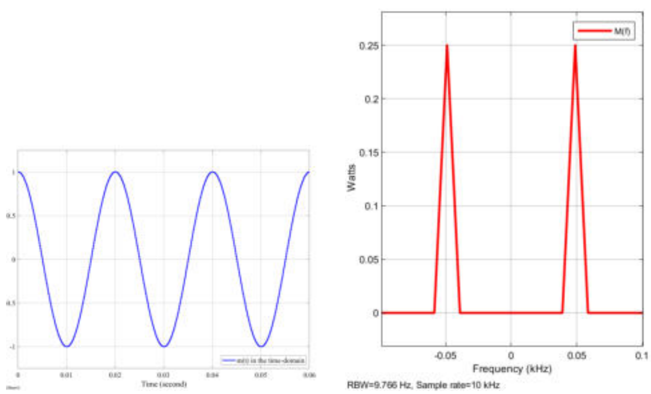
Project 1: Analog Communication via Amplitude Modulation

Ömer Alperen Katı
2021-11-02

I. Part I: Simulink

1) Sampling frequency is selected such that it will be greater than 50 Hz, and there will not be any aliasing.



(a) m(t) in the time-domain (b) m(t) in the freq-domain

Fig. 1

2) It is the distance between the most upper and lower components of the signal's frequency spectrum. In this case, it is 0.05 kHz – (-0.05 kHz) = 0.1 kHz, as can be seen in Fig. 1(b).
3) The Simulink subsystem to implement DSB-SC-AM according to the Eq. 1 can be seen in Fig. 3.

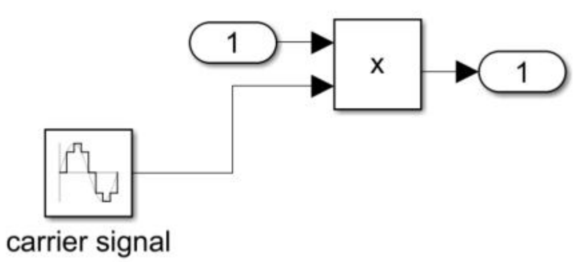
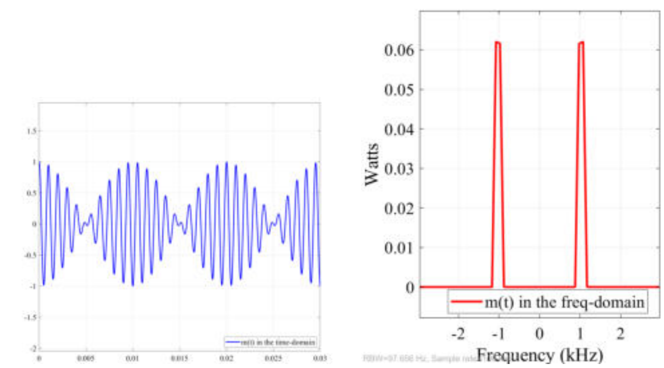


Fig. 2: The Simulink subsystem to implement DSB-SC-AM according to the Eq. 1

$$u(t) = m(t)c(t) \tag{1}$$

4) In the frequency domain, when it is multiplied with the carrier signal, the spectrum will be shifted to $+f_0$ and $-f_0$. Its bandwidth doubles. All these can be observed in Fig. 3(b)

In the time domain, basically the carrier signal is modulated with a message signal. One can see that at every zero crossing there happens a phase reversal. This is also can be seen in Fig. 3(a)



(a) Modulated signal in the time domain (b) Modulated signal in the frequency domain

5) The simulink subsystem to implement conventional AM, taking $\alpha = 0.85$, $w_c = 1000\pi$ rad/s, can be seen in Fig. 3.

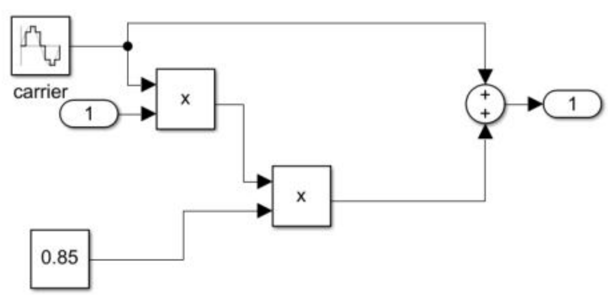


Fig. 3: The Simulink subsystem to implement conventional AM according to the Eq. 4

6) In the time domain, modulated wave is transmitted with the carrier wave. In the frequency domain, since carrier wave is together with the modulated wave, diracs has observed in the middle of the frequency components, which were shifted by f_c.

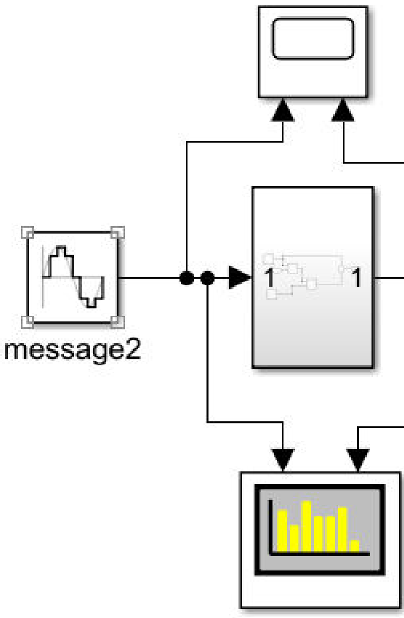
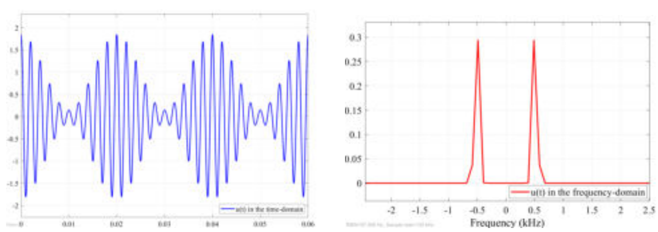


Fig. 4: The model which modules m(t) with the conventional AM using the simulink subsystem in Fig. 3.



(a) (b)

Fig. 5

7)

$$e(t) = m(t)cos^2\omega_c t = m(t)\frac{1+cos(2\omega_c t)}{2} \qquad (2)$$

$$E(f) = \frac{1}{2}M(f) + \frac{1}{4}[M(f+2f_c) + M(f-2f_c)] \qquad (3)$$

The desired component which is centered at f = 0 can be extracted by a low pass filter that suppresses the components centered at $f = +2f_c$ and $-2f_c$. Before low-pass filtering, one can take the amplitude of the carrier as 2 in order to get the exact wave form in terms of amplitude.

The frequency of the local oscillator should be the same with that of carrier signal. The reason is that if a different frequency was used, the shifted components would not merge as it is desired at the center frequency, and then the message signal wouldn't be recovered properly.

The cut-off frequency of the low-pass filter should be adjusted so that it will encompass the desired component but exclude the shifted components.

8) The same subsystem multiplying the modulating signal with a carrier will be employed, and then the resulting waveform will be passed through a low-pass filter, as can be seen in Fig. 6.

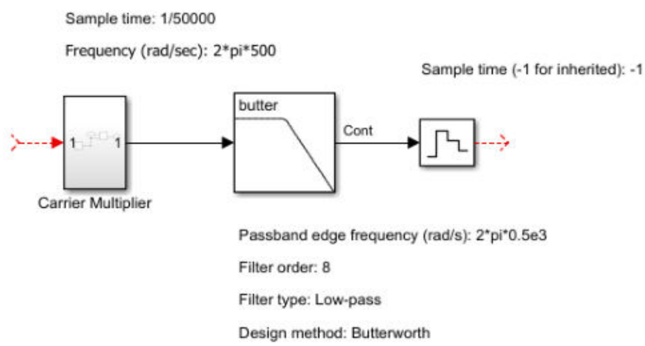


Fig. 6: Synchronous demodulator

9) In the time domain, the message signal is recovered but with a lower peak to peak voltage and a reasonable amount of phase shift.

In the frequency domain, left and right shifted versions of the signal has been summed up to get the baseband component. After that, using low-pass filter, the desired baseband component has been extracted.

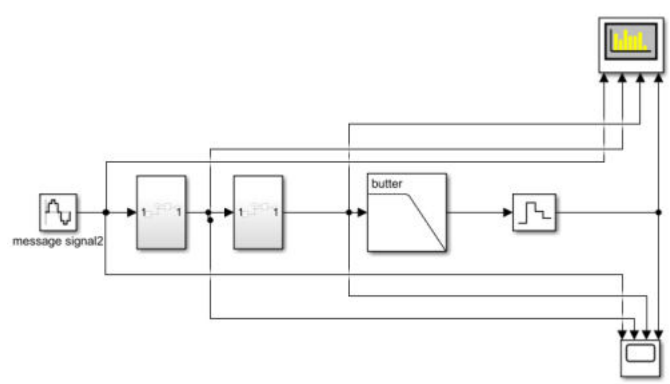
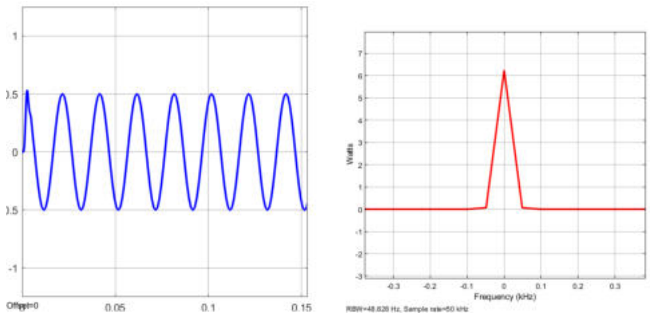


Fig. 7: DSB_SC_AM_SYSTEM



(a) (b)

Fig. 8

10)

$$u(t) = (1 + \alpha m(t))c(t) \tag{4}$$

$$U(f) = \frac{1}{2}(\delta(f - f_c) + \delta(f + f_c)) + \frac{\alpha}{2}(M(f - f_c) + Mlh(f + f_c)) \tag{5}$$

$$2\pi B < 1/RC << w_c \tag{6}$$

11) The subsystem of envelope detector can be seen in Fig. 9 .

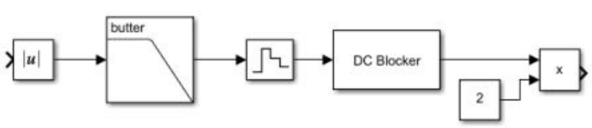


Fig. 9: Envelope detector

12) It can be observed that the recovered signal in the time domain is the same as the message signal in terms of frequency. Its phase and amplitude is different. The amplitudes can be equalized by doubling the amplitude of the carrier signal.

    In the frequency domain, the signal is in the same band width the message signal but only amplitudes are different.

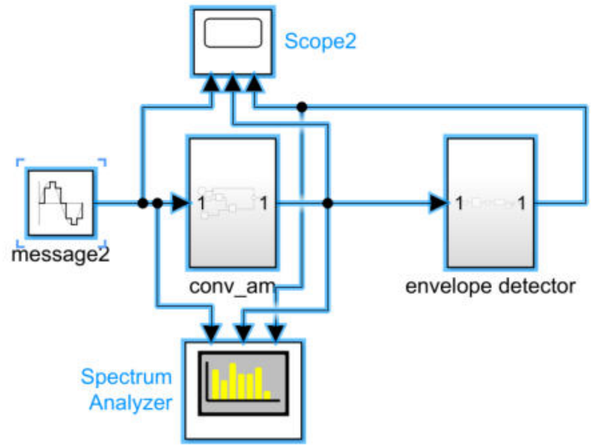
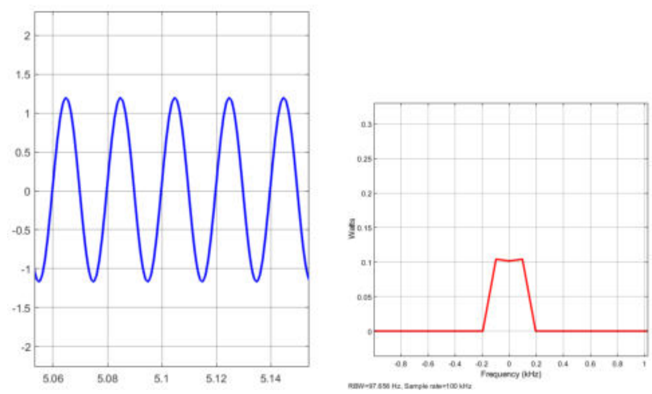


Fig. 10: Conventional Modulation and Envelope Detection

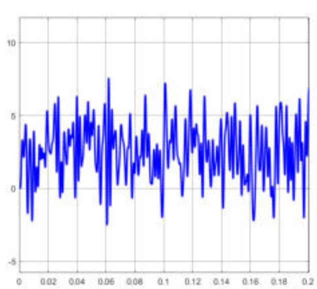


(a) Output of the envelope detector in time domain.
(b) Output of the envelope detector in frequency domain.

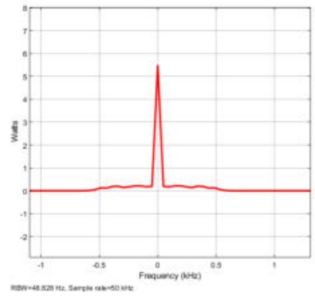
Fig. 11

13) When AWGN is comparatively high, one can see that demodulation in both methods are unsuccessful. As AWGN decreases to reasonable orders, the efficiency of the system enhances, as can be seen in Fig. 12 and 13.

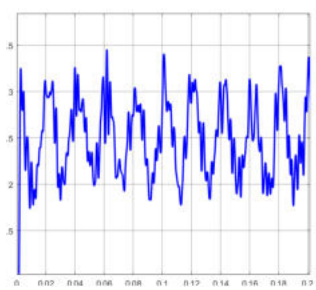
$$r(t) = u(t) + n(t) \tag{7}$$



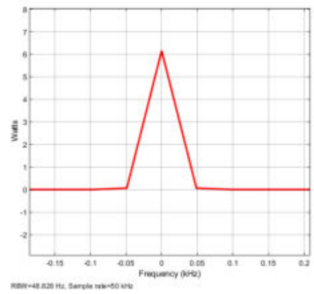
(a) Time domain for $P_n = 10^{-2}$



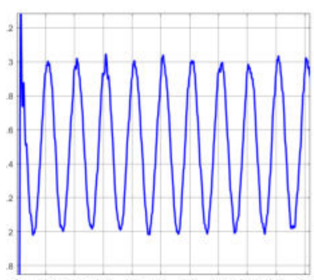
(b) Frequency domain for $P_n = 10^{-2}$



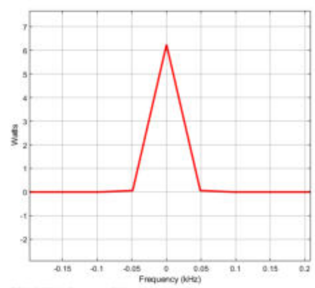
(c) Time domain for $P_n = 10^{-4}$



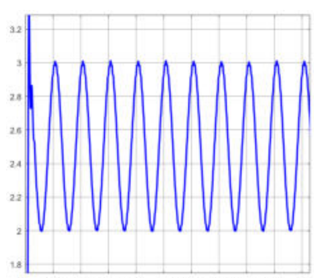
(d) Frequency domain for $P_n = 10^{-4}$



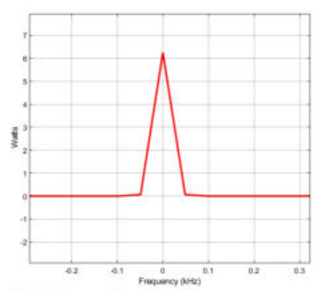
(e) Time domain for $P_n = 10^{-6}$



(f) Frequency domain for $P_n = 10^{-6}$

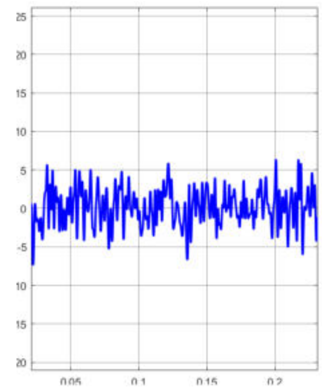


(g) Time domain for $P_n = 10^{-8}$

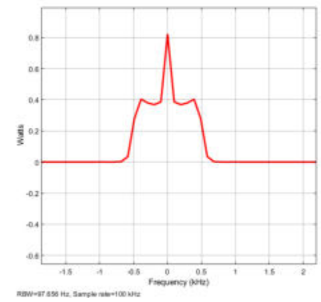


(h) Frequency domain for $P_n = 10^{-8}$

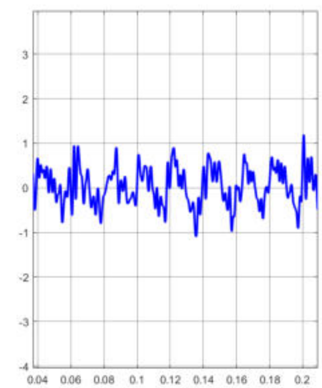
Fig. 12: The demodulation output plots of DSB-SC-AM system in both time and frequency domain for different AWGNs.



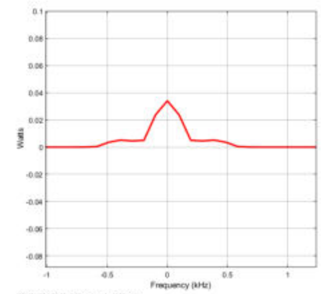
(a) Time domain for $P_n = 10^{-2}$



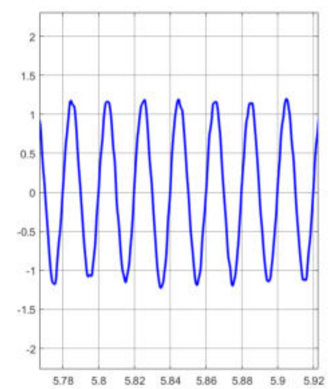
(b) Frequency domain for $P_n = 10^{-2}$



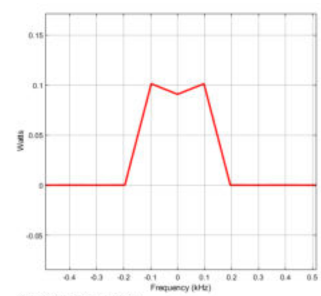
(c) Time domain for $P_n = 10^{-4}$



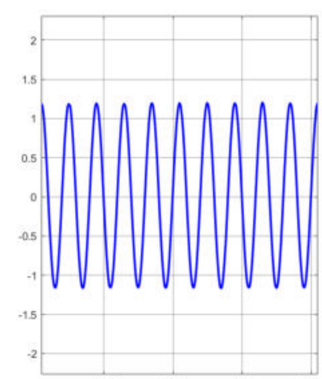
(d) Frequency domain for $P_n = 10^{-4}$



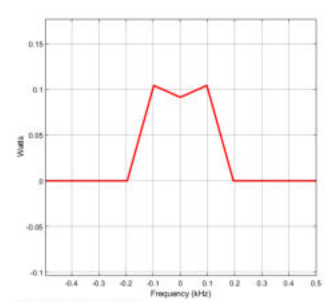
(e) Time domain for $P_n = 10^{-6}$



(f) Frequency domain for $P_n = 10^{-6}$



(g) Time domain for $P_n = 10^{-8}$



(h) Frequency domain for $P_n = 10^{-8}$

Fig. 13: The demodulation output plots of conventional AM system in both time and frequency domain for different AWGNs.