Project 2: Analog Communication via Frequency Modulation

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I. Part I: Simulink

1) The source designed to generate m(t) can be seen in Fig. 1.

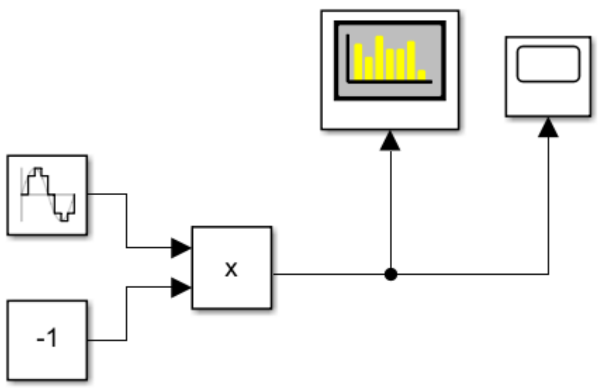
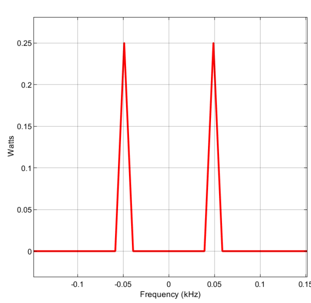
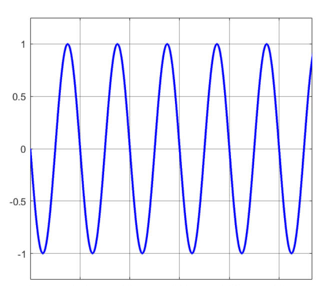


Fig. 1: The source designed to generate m(t).

The message has verified with the help of scope and the spectrum analyzer as can be seen in Fig. 2(a) and 2(b).



(a) m(t) in spectrum analyzer



(b) m(t) in scope

Fig. 2

2) It has an infinitesimally small bandwidth at 0.05 kHz.
3) The designed simulink system to implement frequency modulation can be seen in Fig. 3.

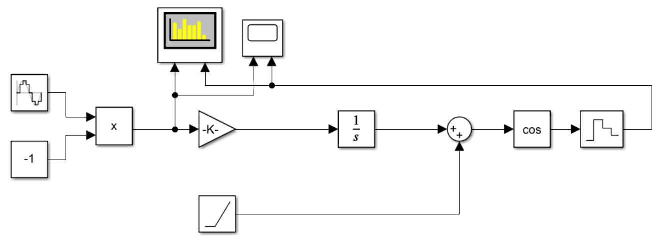
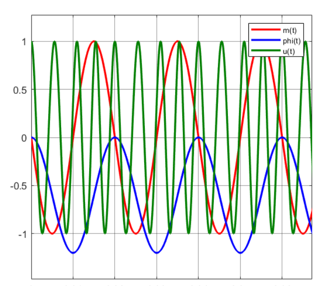
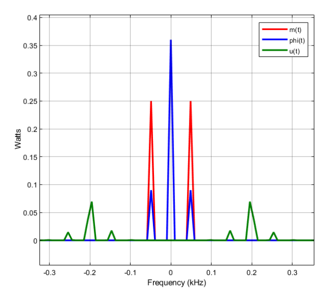


Fig. 3: The designed simulink system to implement frequency modulation.

4) The time- and frequency-domain plots of m(t), the integral of the message signal and the modulated signal u(t) can be seen in Fig. 4(a) and 4(b). m(t) is as expected, being two direc deltas at frequency of m(t), and $\phi(t)$ is the same with m(t) but with an extra DC component. u(t) has dirac deltas at carrier frequency but with a variation since the frequency is modulated.



(a) The time-domain



(b) The frequency-domain

Fig. 4: Plots of m(t), the integral of the message and the modulated signal u(t).

5) u(t) can be represented as weighted sum of higher order harmonics, as can be seen in Fig. 5.

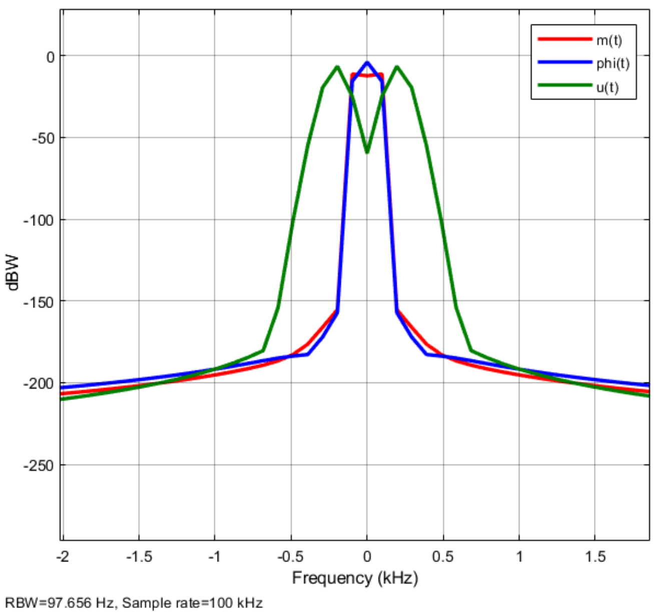


Fig. 5: The frequency spectrums of m(t), $\phi(t)$ and u(t).

$$u(t) = \sum_{n=0}^{\infty} A_c J_n(\beta_f) cos(2\pi(f_c + n f_m)t) \tag{1}$$

6) The bandwidth of the modulated signal can be found according to the Carson's rule as follows:

$$\beta_T = 2(\beta_f + 1) = 2(\frac{30 \times 1}{50} + 1)50 = 160\text{Hz} \tag{2}$$

However, the bandwidth has been observed as 292.969 Hz, as can be seen in Fig. 6. The observed value is greater than the calculated since Carson's rule approximates the bandwidth that most of the signal energy is carried.

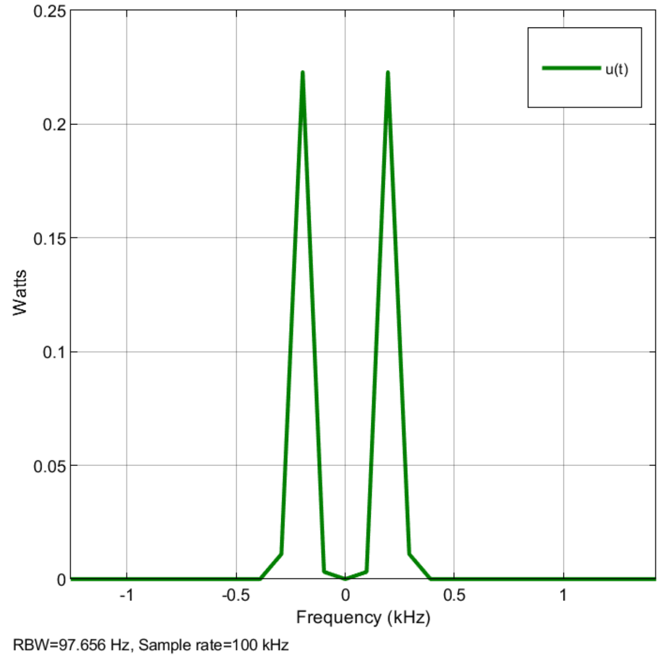


Fig. 6: The observed frequency spectrum of u(t).

7) We can use phase locked loop as a demodulator since it gives the phase difference between m(t) and a reference signal from VCO. This reference signal is controlled by the low pass filtered output of phase detector.
8) The overall model with phase locked loop can be seen in Fig. 7.

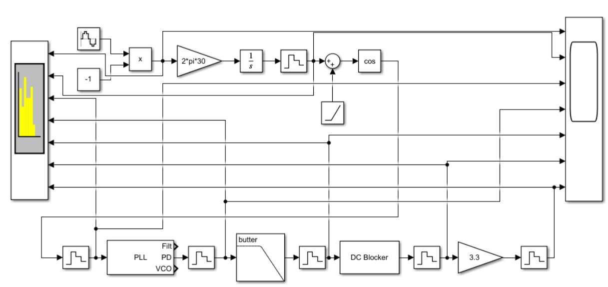


Fig. 7: The overall model with phase locked loop

9) The time- and frequency-domain plots of m(t) and $\phi(t)$ can be seen in Fig. 8. m(t) can be extracted using low pass filter, dc blocker and amplifier, respectively.

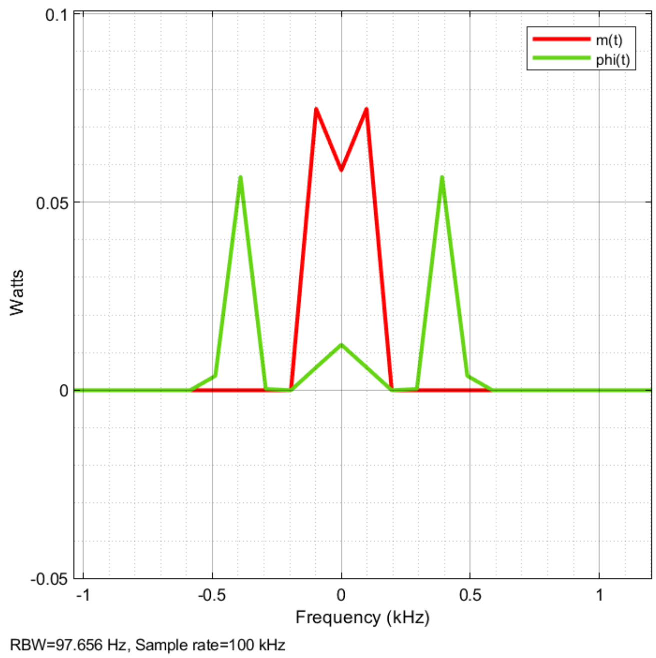


Fig. 8: The time- and frequency-domain plots of m(t) and $\phi(t)$

10) PLL demodulator subsystem can be seen in Fig. 9. The overall FM modulation and demodulation system can be seen in Fig. 10.

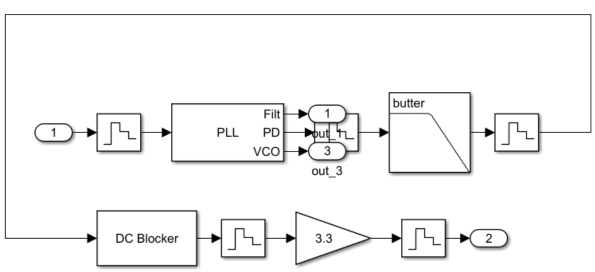


Fig. 9: PLL demodulator subsystem

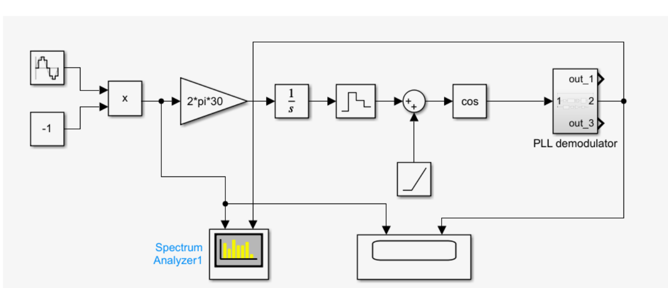
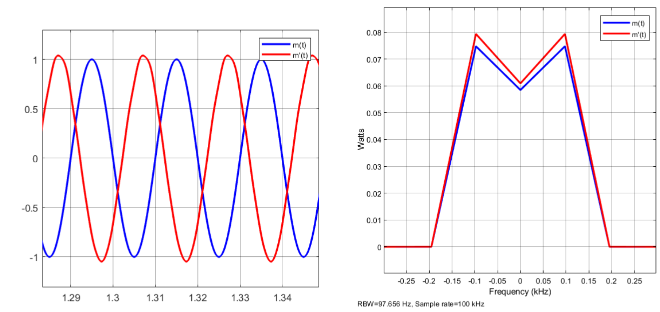


Fig. 10: Overall FM modulation and demodulation system.



(a) The time-domain (b) The frequency-domain

Fig. 11: Plots of m(t) and m'(t).