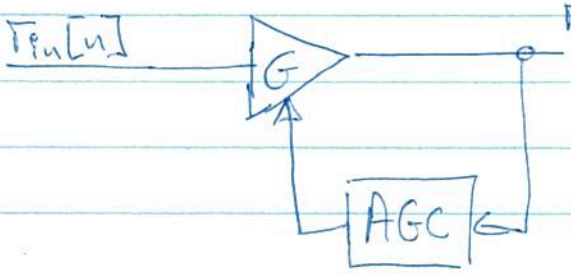
Dr. Paris

HW #6 Solution ECE 460

P.1:



Power can be measured by computing:

$$P_{meas}[n] = \frac{1}{N_{avg}} \cdot \sum_{k=n}^{n-N_{avg}+1} \left(r_{out}[k]\right)^2$$

Want $P_{meas}[n]$ to approach P_{des} by adjusting G.

$\Rightarrow$ Objective Function:

$$J(G;n) = \left(P_{des} - P_{meas}[n]\right)^2$$

$$= \left(P_{des} - \frac{1}{N_{avg}} \sum_{k=n}^{n-N_{avg}+1} \left(r_{out}[k]\right)^2\right)^2$$

$$= \left(P_{des} - \frac{1}{N_{avg}} \sum_{k=n}^{n-N_{avg}+1} \left(G[n] \cdot r_{in}[k]\right)^2\right)^2$$

$$= \left(P_{des} - \frac{G^2[n]}{N_{avg}} \sum_{k=1}^{n-N_{avg}+1} \left(r_{in}[k]\right)^2\right)^2$$

Iterative update:

$$G[n+1] = G[n] - \mu \cdot \left.\frac{\partial J(G;n)}{\partial G}\right|_{G=G[n]}$$

Need: $\left.\frac{\partial J(G;n)}{\partial G}\right|_{G=G[n]} = 2 \cdot \Big(P_{des} - \overbrace{\frac{G[n]}{N_{avg}} \cdot \sum_{k=n-N_{avg}+1}^{n} \big(r_{in}[k]\big)^2}^{= P_{meas}[n]} \Big) \cdot$

$$\Big(-2 \cdot \underbrace{\frac{G[n]}{N_{avg}} \cdot \sum_{k=n-N_{avg}+1}^{n} \big(r_{in}[k]\big)^2}_{P_{meas}[n]/G[n]} \Big)$$

$$= -4 \cdot \big(P_{des} - P_{meas}[n]\big) \cdot \frac{P_{meas}[n]}{G[n]}$$

$\Rightarrow$ Update:

$$G[n+1] = G[n] + 4\mu \cdot \big(P_{des} - P_{meas}[n]\big) \cdot \frac{P_{meas}[n]}{G}$$

Note: this formula ensures that if $P_{meas} < P_{des}$ then gain G is increased and vice versa.

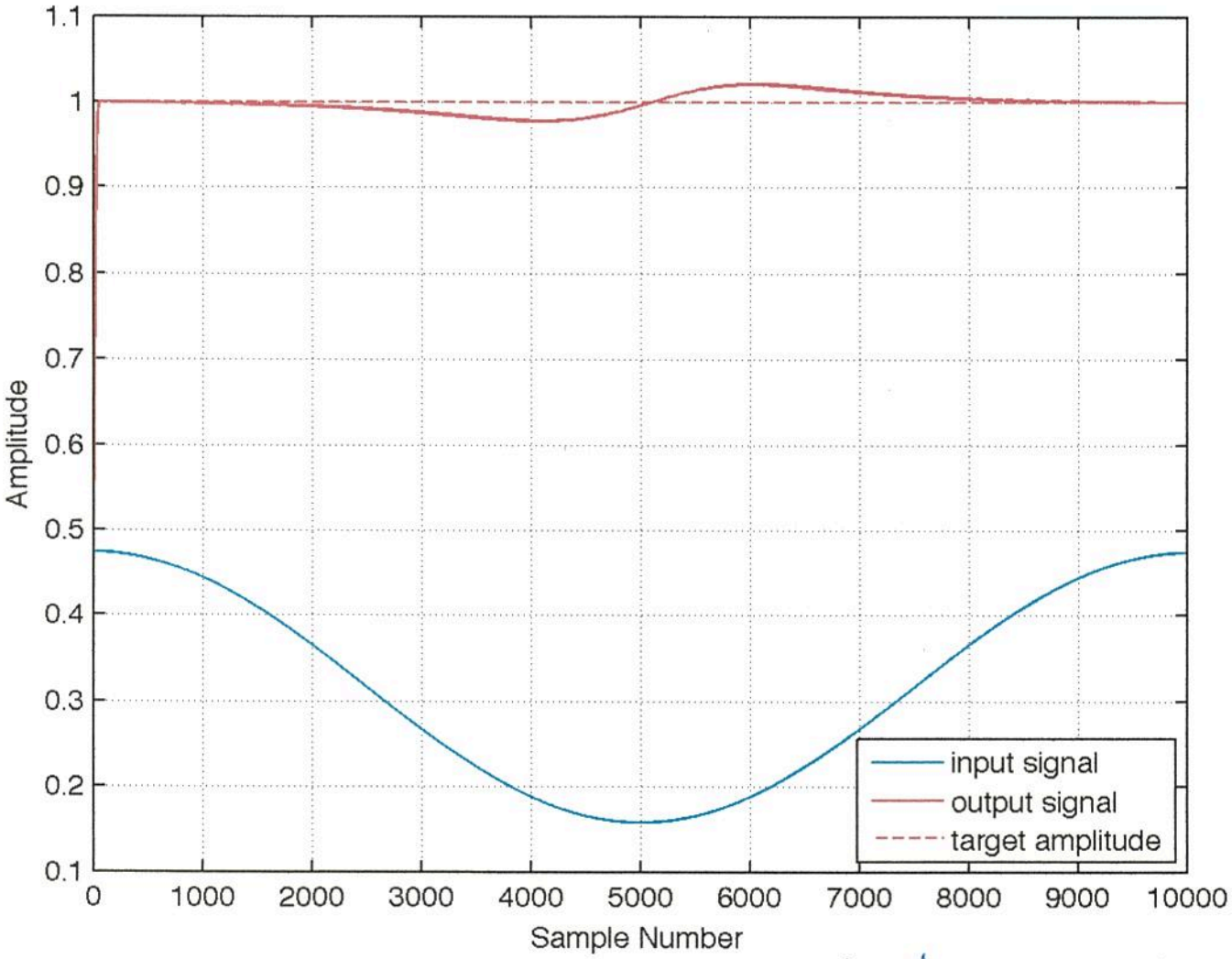
See AGC.m (in http://spec.gmu.edu/~ppan/classes/resources_460) for MATLAB Demo.

all MATLAB files are here.

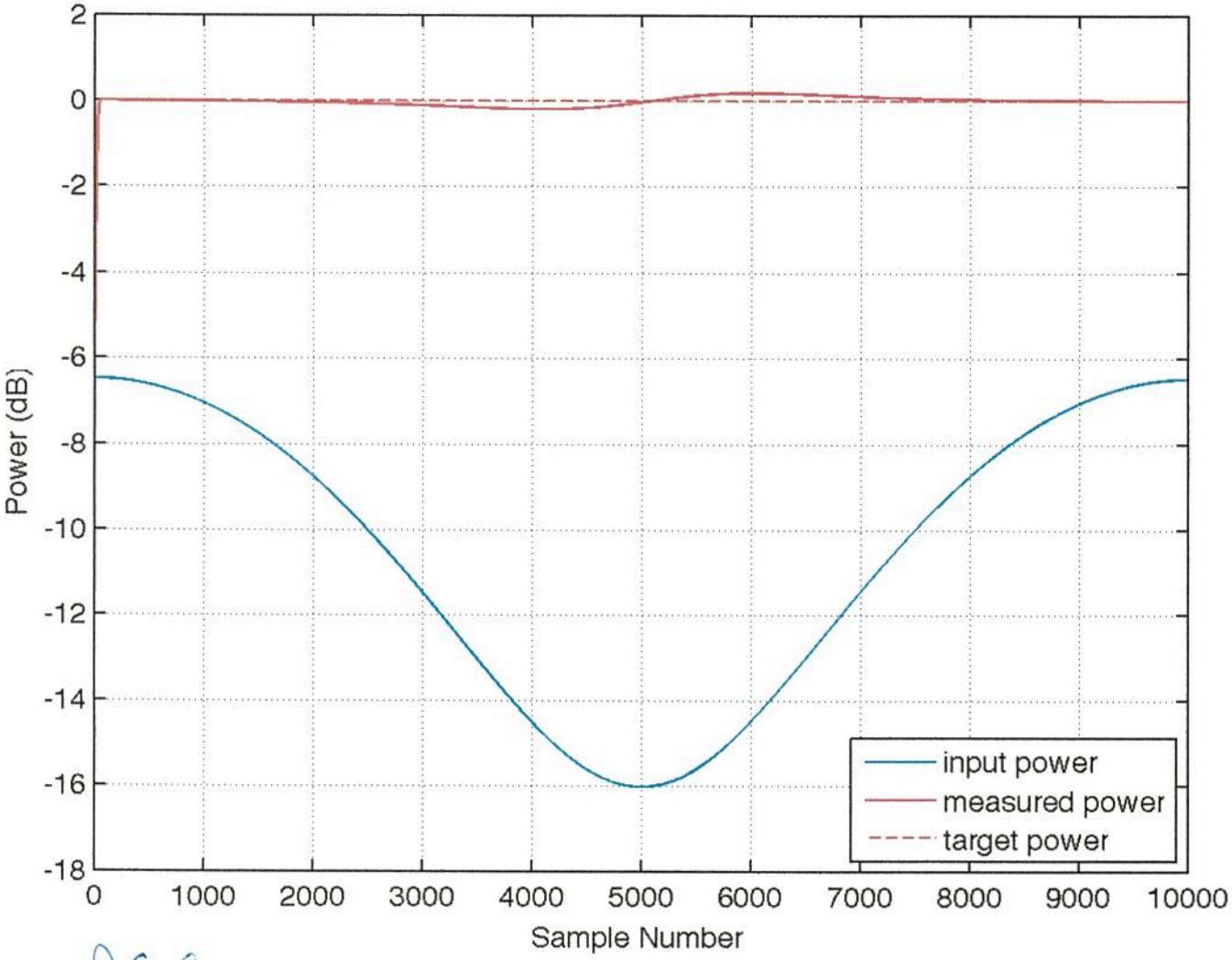
See attached plots.

AGC.m:

- constant (all ones) input signal
- amplitude/power is slowly time-varying
  + see blue line below



=> AGC tracks gain such that output amplitude (solid red line) remains close to target amplitude ($\sqrt{P_{des}}$).



AGC:

- plot of powers in dB
- blue: input power / time-varying
- solid red: output power with AGC remains with < 1dB of target power (red dashed)

P3

Amplitude modulation function is implemented in

- ampModulate.m

- See comments in that function for implementation details:

demo_ampModulate.m provides test script for this function:

Demo 1: $f_m = 1$ - sinusoidal message
$f_c = 8$ - carrier frequency

see attached plot of passband signal

Demo 2: - message signal is a speech signal
- $f_c = 8$ kHz - carrier frequency

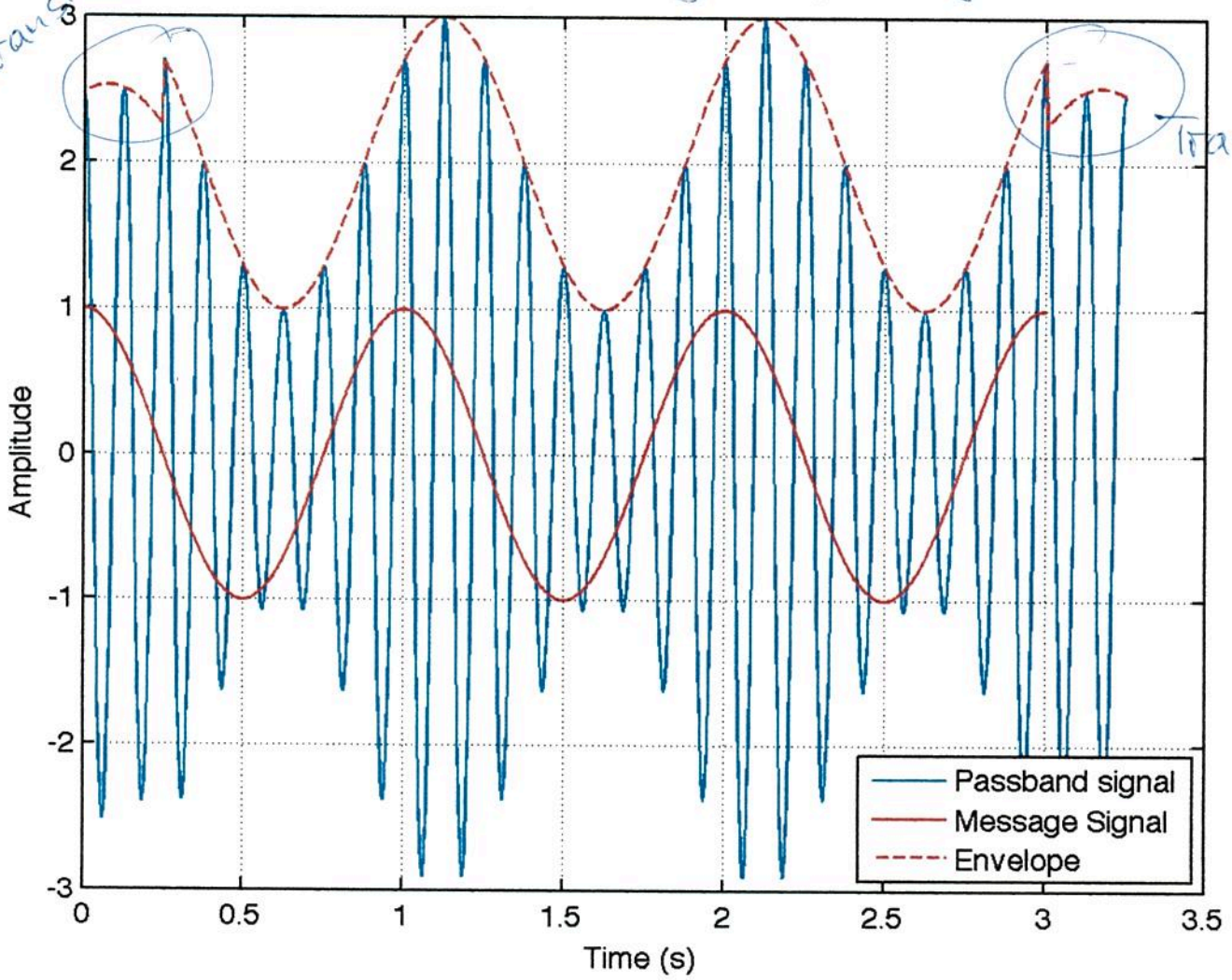
see attached plot of PSD of passband signal

P4: Function - ampDemodulate.m (no synch)
Demo: - demo_ampDemodulate.m
shows demodulation of 2 signals above.

demo_ampModulate.m: Demo 1: $m(t)$

- Sinusoidal message signal (solid red) ✓
- modulated signal / passband signal (solid blue)
- 8 carrier cycles per signal period. ✓

Transient



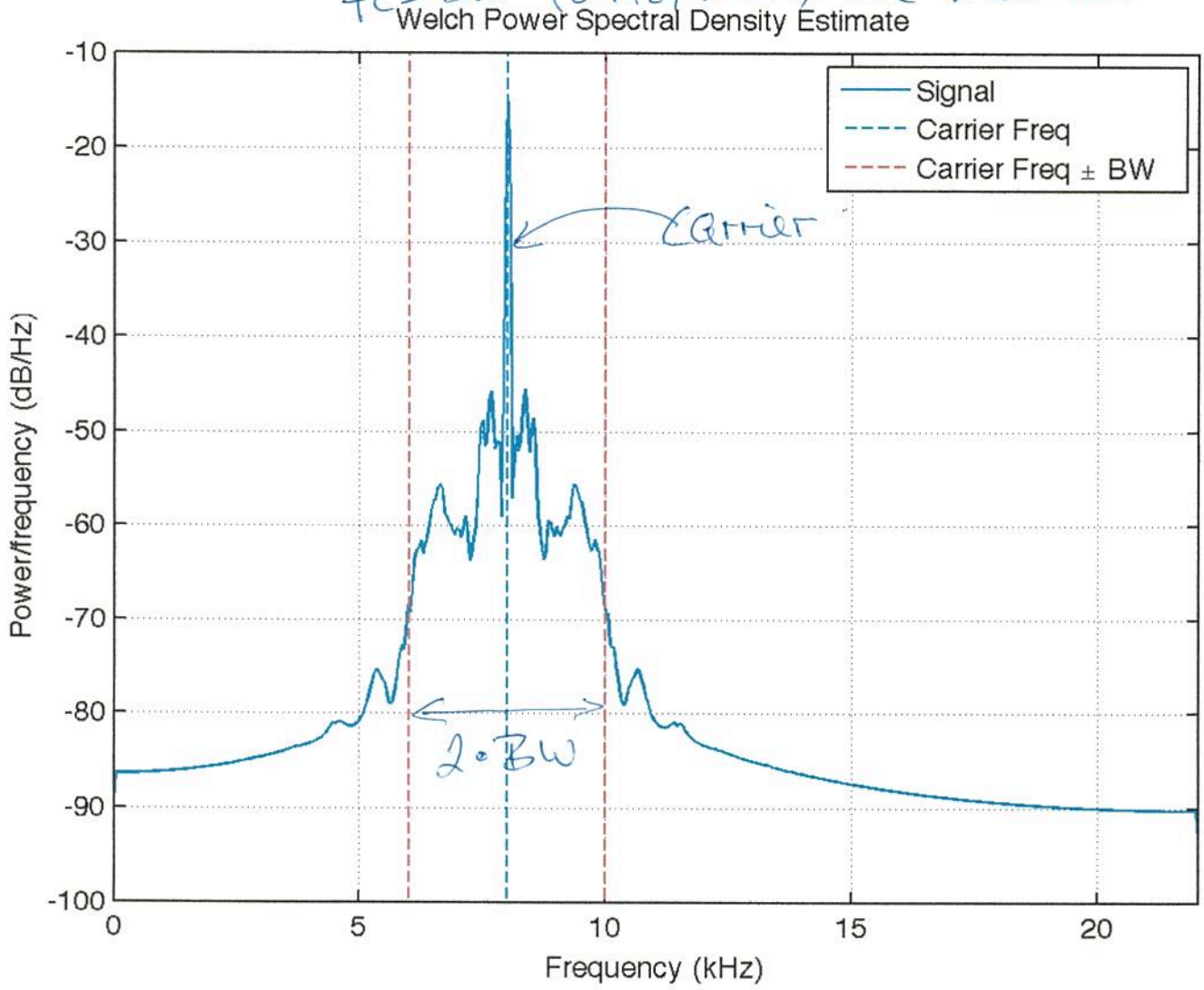
Transient

- dashed red: envelope signal: $A_c + m(t)$.

- Note: Filter in ~~cde~~ modulator induces:
  - delay (25 samples)
  - transients at start and end.

demo_ampModulate.m: Demo 2

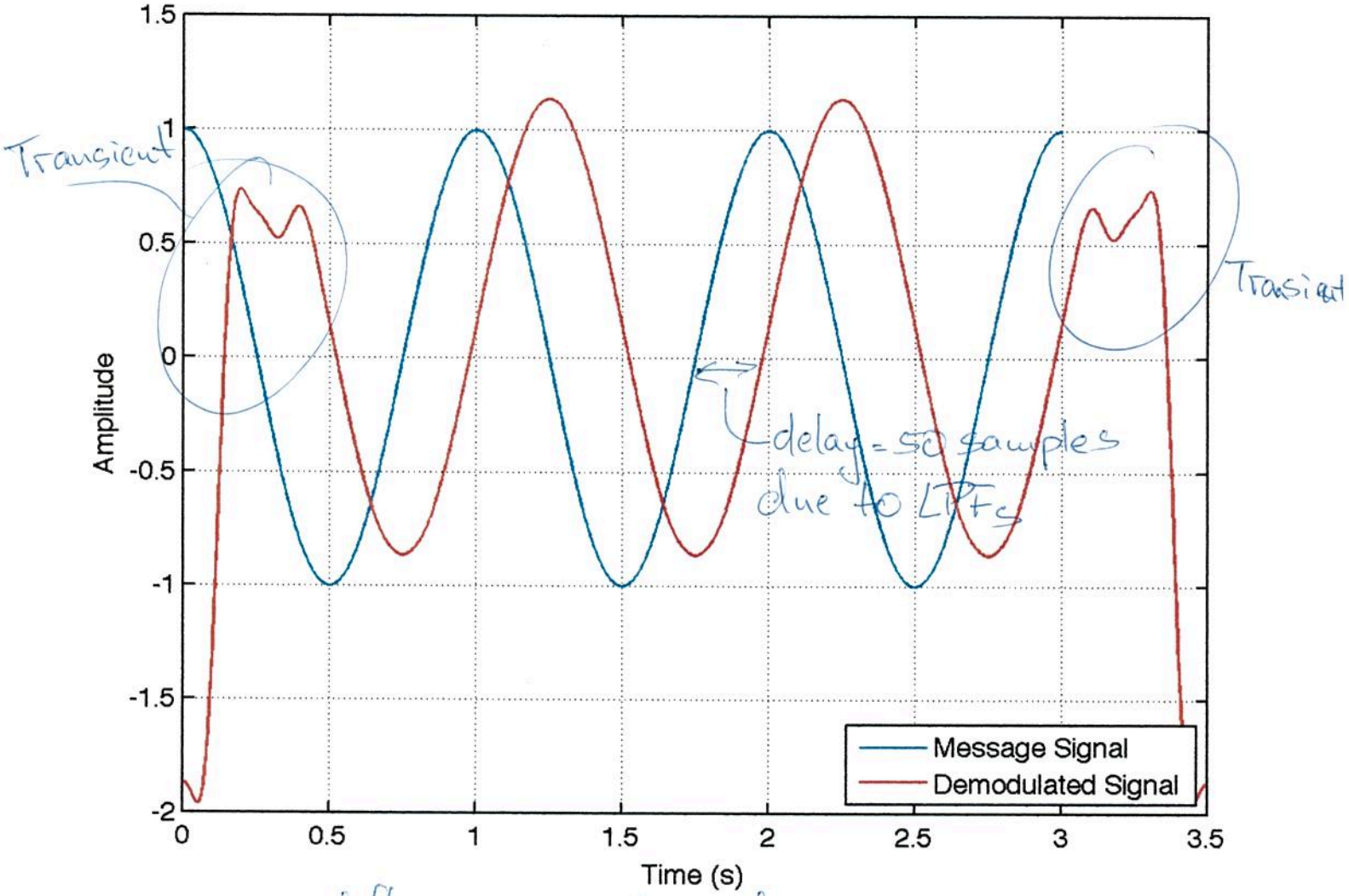
- $m(t)$ = speech signal
- plot shows power spectral density (PSD) of passband signal.
- location of center frequency (8kHz) and $f_c \pm BW$ (6kHz / 10kHz) are marked.



- signal is clearly centered at f_c.
  - carrier is visible ($a_{mod} = 50\%$)
- At passband, signal is limited to $f_c \pm BW$ ($BW = 2$kHz)

demo_ampDemodulate: Demo 1

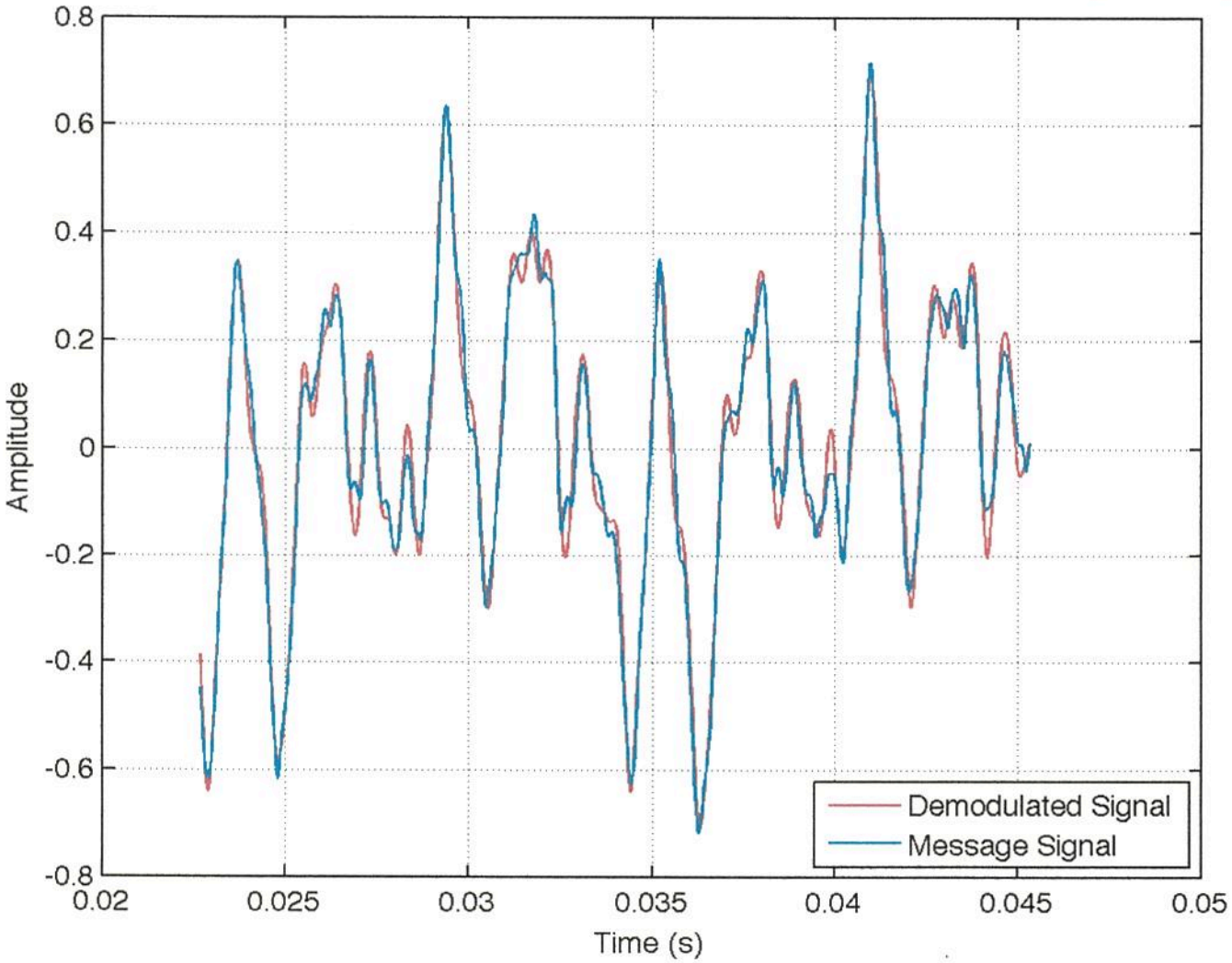
- Plot shows
  + original signal (blue)
  + demodulated signal (red)



- differences arise from:
  - transients due to filtering at both ends of demodulated signal
  - delay (50 samples) from filtering
  - small vertical offset due to incomplete carrier removal.

demo_ampDemodulate.m: Demo 2

- Plot shows: (~20ms)
  + original message signal (blue)
  + demodulated signal (red)
- Note: delay induced by 2 LP filters (50 samp was compensated to align signals



- Very good agreement:
  - differences are due to filtering or imperfect suppression of double-frequency terms.