Lecture 10: Amplitude Modulation (Double Sideband *Large Carrier*, DSB-LC *or* AM)

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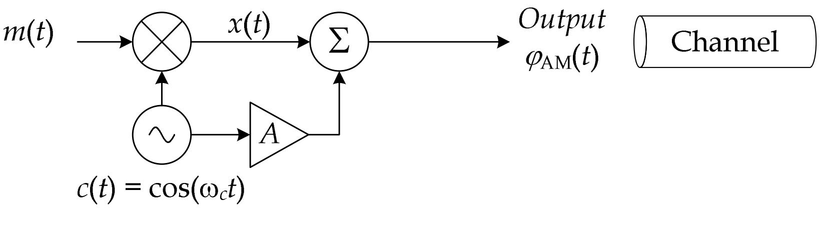
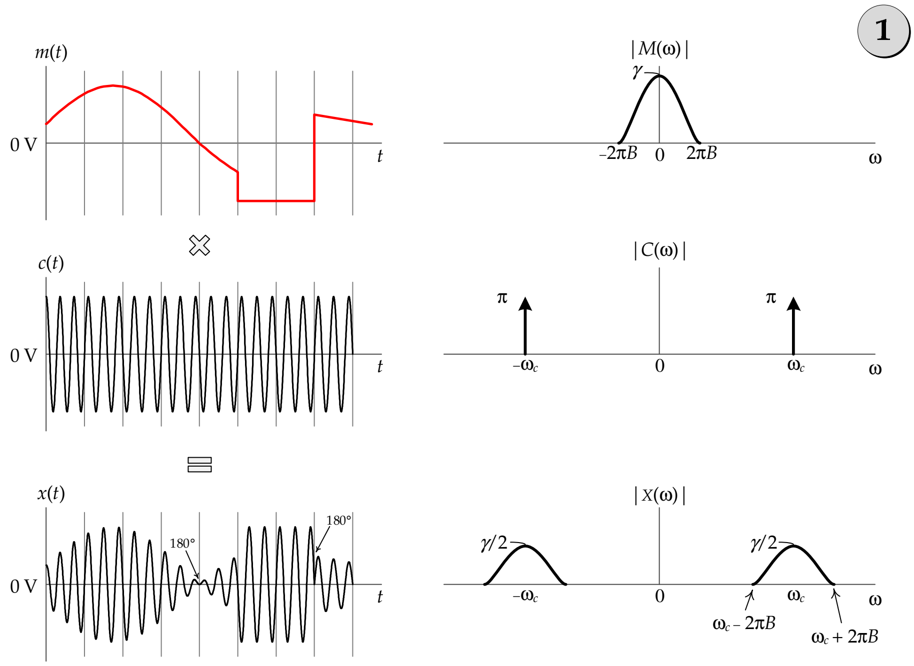
EE421: Communications I. For more information read Chapter 4 in your textbook or visit http://wikipedia.org/.

AM Modulator (*Method #1*)



- Three possibilities (based on the value of A):
  - *Under* modulation; $m < 1$
  - *Critical* modulation; $m = 1$
  - *Over* modulation; $m > 1$



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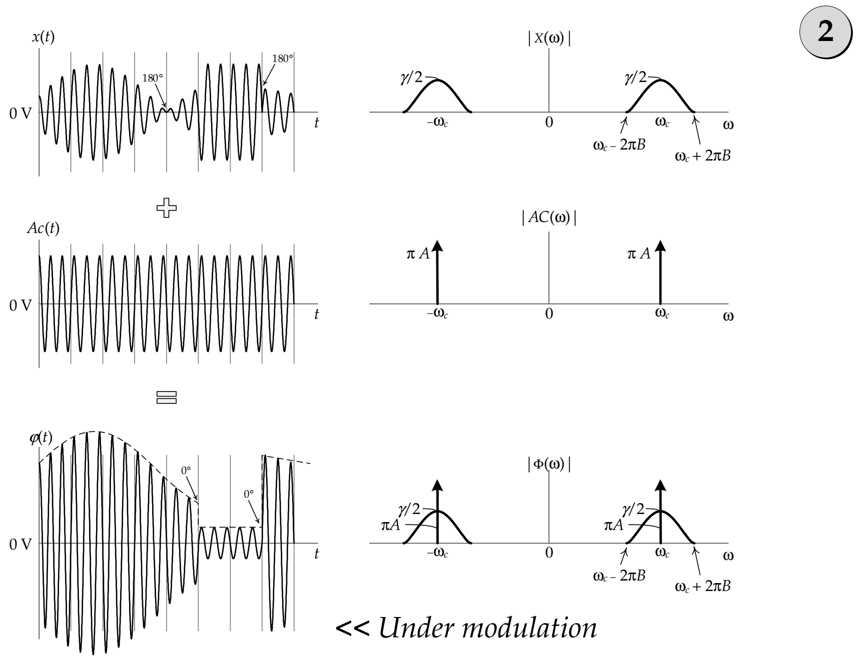

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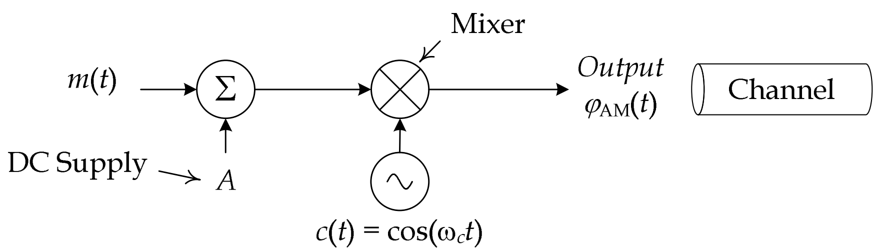
AM Modulator (*Method* #2)



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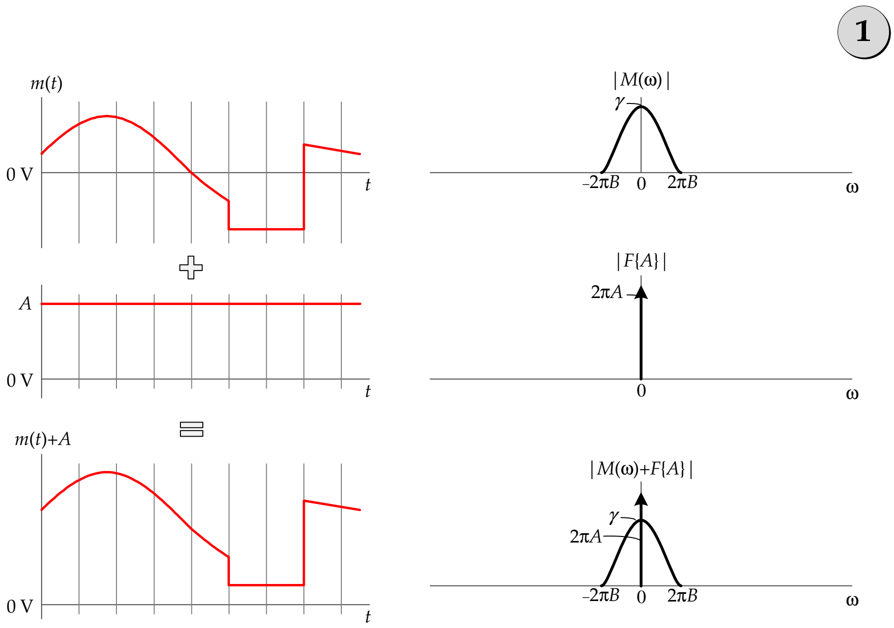
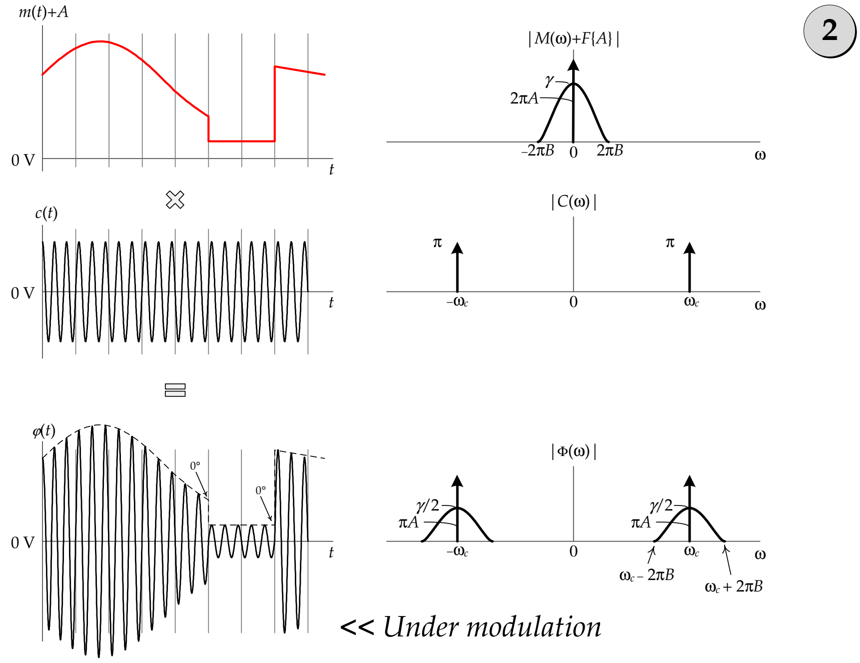
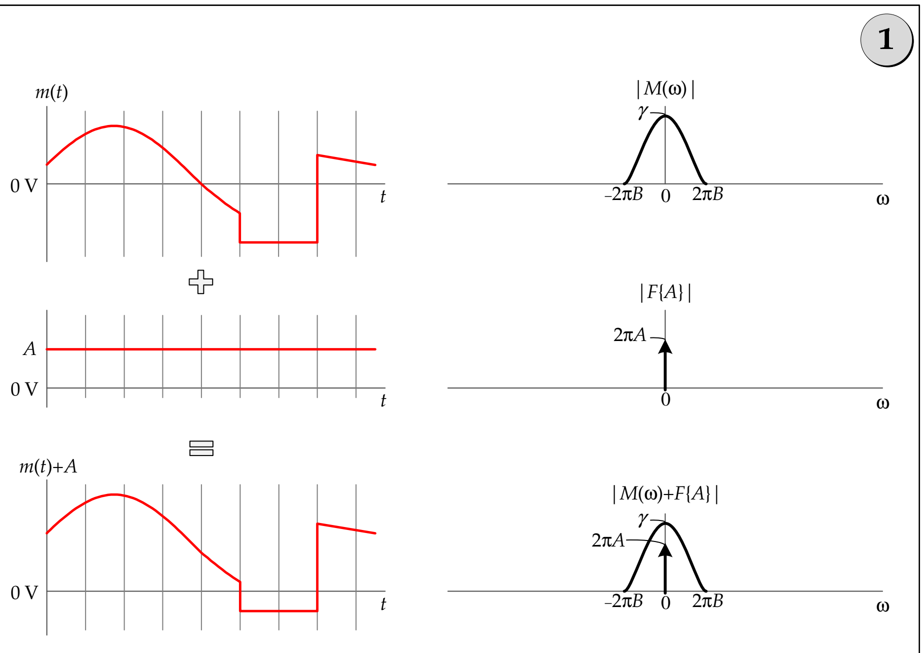
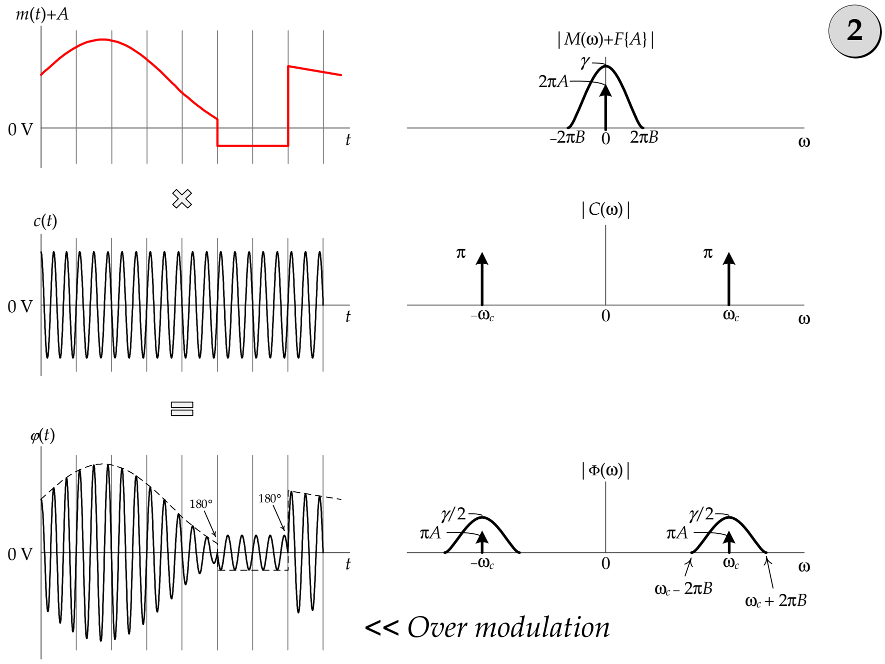


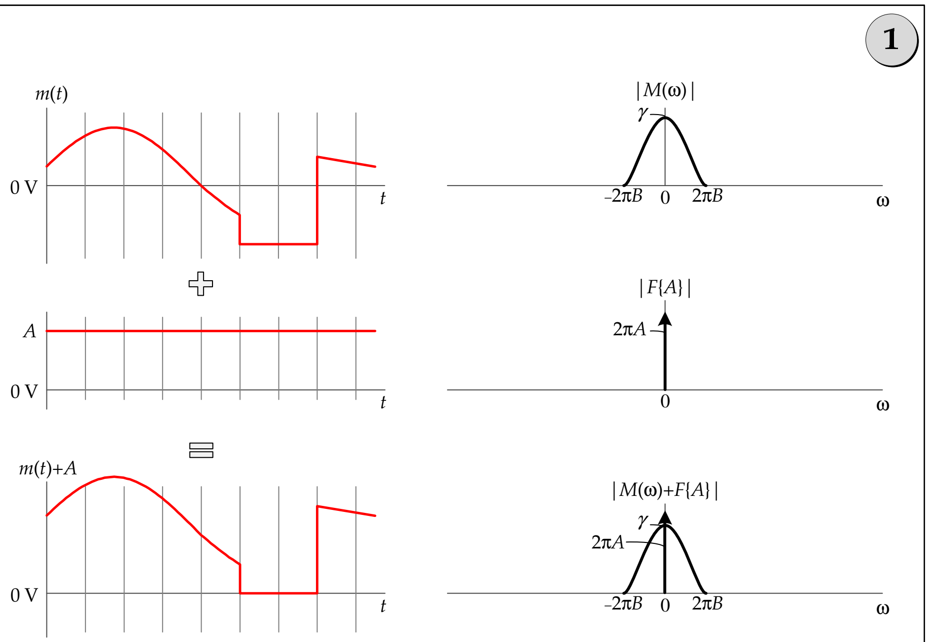


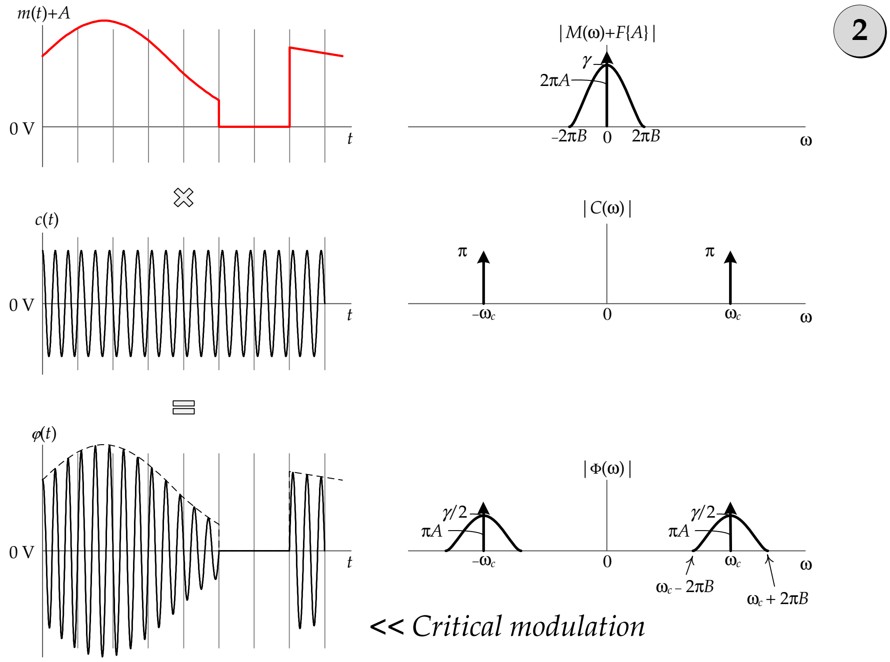
<< *Under modulation*





<< *Over modulation*





<< *Critical modulation*

AM Modulation Index, m

More power needed from transmitter (Larger A)

$$m \triangleq \frac{-m(t)_{min}}{A}$$

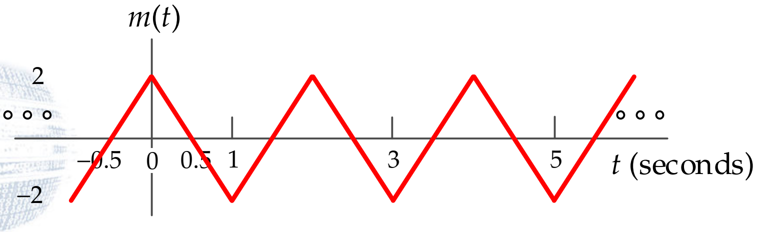
- $m < 1$, $m = 1$: *Asynchronous* (*incoherent*) receivers can demodulate (Very *simple* and very *inexpensive*)
- $m > 1$, $m = \infty$: Only *synchronous* (*coherent*) receivers can demodulate. Such RX requires using a PLL (*Expensive*)

Point-to-Point vs Broadcasting

Homework

If we perform AM modulation on the following baseband message signal $m(t)$ using $m = 0.5, 1, 2, \infty$:

- Sketch the modulated signal in ***time domain*** $\varphi_{AM}(t)$
- Sketch the ***frequency domain*** Fourier Transform $\Phi_{AM}(\omega)$
- Determine the modulated signal ***bandwidth***.



Example

Sketch the AM modulated signal in ***time domain*** $\varphi_{AM}(t)$ and ***frequency domain*** $\Phi_{AM}(\omega)$, then calculate the modulated signal ***bandwidth, average power, power efficiency***. Assume the case of *tone modulation*, and:

- $m = 0.5$
- $m = 1$
- $m = 2$
- $m = \infty$

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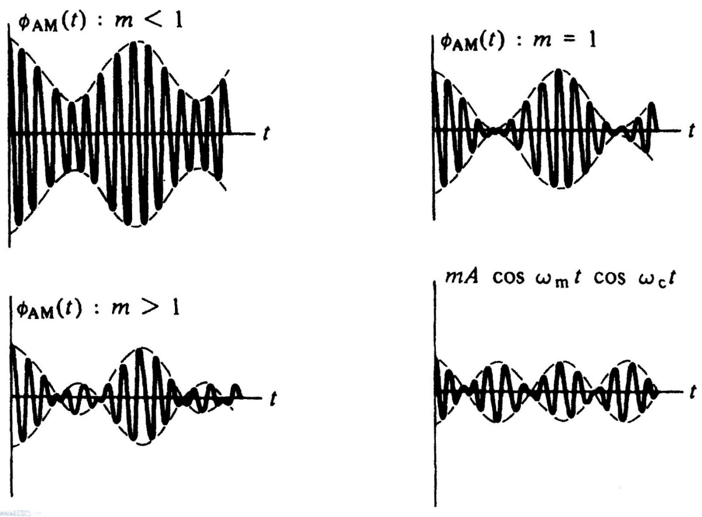

$$m = \frac{\textbf{max}.\,magnitude - \textbf{min}.\,magnitude}{\textbf{max}.\,magnitude + \textbf{min}.\,magnitude}$$

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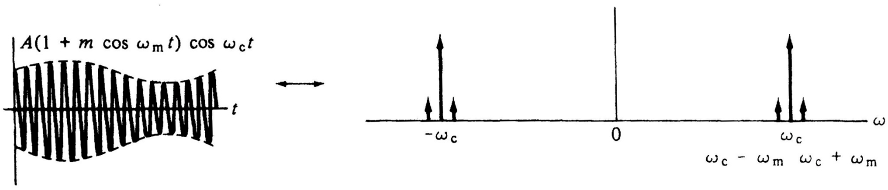
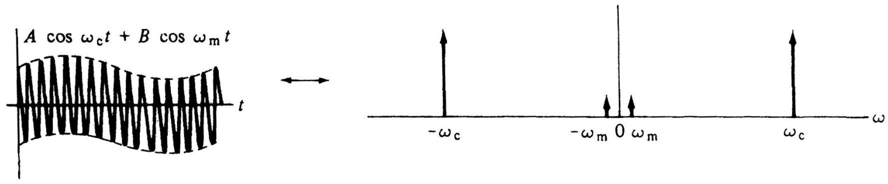
Notice the Difference!





AM Average Power

$$P_{\varphi_{AM}(t)} = \overline{\varphi_{AM}^2(t)} = \lim_{T\to\infty}\frac{1}{T}\int_T \varphi_{AM}^2(t)dt$$

$$\overline{\varphi_{AM}^2(t)} = \overline{[m(t)\cos(\omega_c t) + A\cos(\omega_c t)]^2}$$

$$\overline{\varphi_{AM}^2(t)} = \overline{m^2(t)\cos^2(\omega_c t) + A^2\cos^2(\omega_c t) + 2Am(t)\cos^2(\omega_c t)}$$

$$\overline{\varphi_{AM}^2(t)} = \overline{m^2(t)\cos^2(\omega_c t)} + A^2\,\overline{\cos^2(\omega_c t)} + 2\overline{Am(t)\cos^2(\omega_c t)}$$

$$\overline{\varphi_{AM}^2(t)} = \frac{1}{2}\overline{m^2(t)} + \frac{A^2}{2} + A\overline{m(t)} = P_s + P_c + P_x = P_s + P_c + 0$$

AM Power Efficiency

$$\eta = \frac{Useful\ power}{Total\ power} = \frac{P_s}{P_t} = \frac{P_s}{P_s + P_c + P_x}$$

$$\eta = \frac{\frac{1}{2}\overline{m^2(t)}}{\frac{1}{2}\overline{m^2(t)} + \frac{A^2}{2} + A\overline{m(t)}} \qquad (general)$$

$$\eta = \frac{m^2}{m^2 + 2} \qquad (tone\ modulation)$$

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Power Efficiency Disadvantage

m	η (tone modulation)	
0.5	$\frac{0.5^2}{0.5^2 + 2} = 0.1111$	11.11%
1	$\frac{1^2}{1^2 + 2} = 0.3333$	33.33%
2	$\frac{2^2}{2^2 + 2} = 0.6667$	66.67%
∞	$\eta = \frac{\frac{1}{2}\overline{m^2(t)}}{\frac{1}{2}\overline{m^2(t)} + 0 + 0}$	100%

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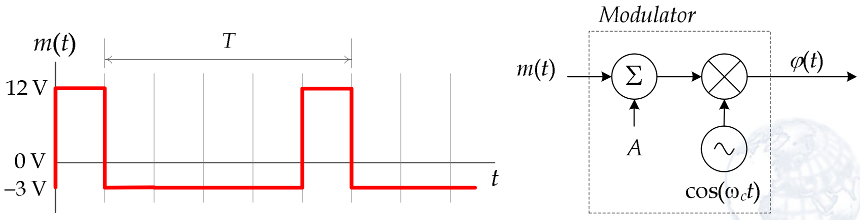
Homework #1

- A given AM (DSB-LC) broadcast station transmits an average carrier power, P_c , of 40 kW and uses a modulation index, m, of 0.707 for *tone* modulation. *Assuming* the antenna is represented by a 50 Ω resistive load, calculate:
  - The transmission efficiency (η).
  - The total average power output (P_t).
  - The *extra carrier* amplitude (A).
  - The peak amplitude of the output signal.
  - *Answers*: 20%; 50 kW; 2000 V; 3414 V.

Homework #2

- The baseband signal $m(t)$ shown is passed through the following modulator. Assume the power efficiency is 90%, T = 60 μs and f_c = 40 MHz. Determine:



Homework #2

- Type of the modulated signal $\varphi(t)$?
- Bandwidth of the modulated signal?
- Average power in the sidebands P_s?
- Average power in the extra carrier P_c?
- Modulation index of the modulated signal?
- Magnitude spectrum density of the modulated signal $|\Phi(\omega)|$ at $\omega=\omega_c-2\pi/T$?
- *Answers*: AM; 166.67 kHz; 18 W; 2 W; 1.5; $2\pi\times1.403\ \delta(\omega-\omega_c+2\pi/T)$;

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AM vs. DSB-SC

- Both require the same transmission bandwidth (equal to $2B$).
- DSB-SC allows for a more efficient *transmitter* (power savings).
- AM allows for a cheaper *receiver* (asynchronous demodulator), while DSB-SC only works with synchronous detection.

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AM vs. QAM

- **Advantages of QAM:**
  - QAM is more bandwidth efficient than AM, allowing us to send two signals on the same channel (of bandwidth 2*B*).
  - QAM allows for more power efficiency at the transmitter.
- **Disadvantages of QAM:**
  - AM can be demodulated using cheap asynchronous demodulators, but QAM only works with synchronous detection (because of orthogonality).
  - There is *NO* such thing as QAM-LC.