Lecture 7: Heterodyning
(*Up & Down Frequency Converter*)

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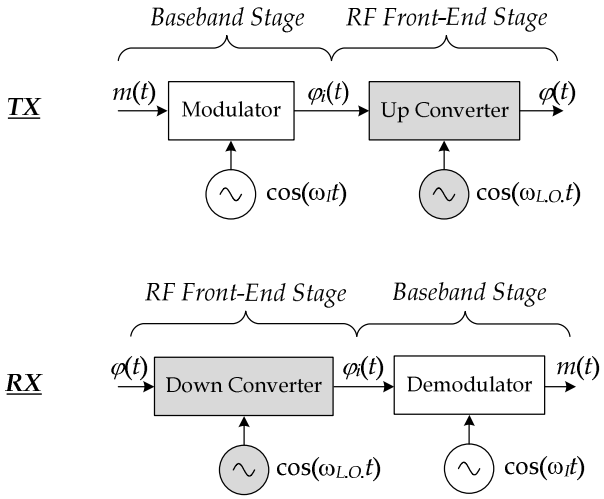
Heterodyne: Multiple Frequencies

- Typical **transmitters** do not modulate immediately from baseband to carrier frequency ω_c. Rather, they modulate to an *intermediate frequency* ω_I, then an up-converter shifts the frequency to the higher frequency ω_c.
- Also, real-life **receivers** do not demodulate immediately from carrier frequency ω_c to baseband. Rather, they use a down-converter to shift the modulated signal to an *intermediate frequency* ω_I, then demodulate to baseband.
- This has advantages, especially in FDM systems and digital systems (see: super-heterodyne receiver).

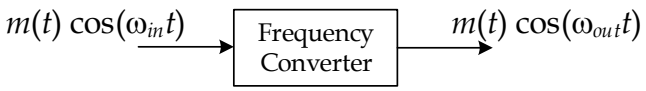
Frequency Conversion

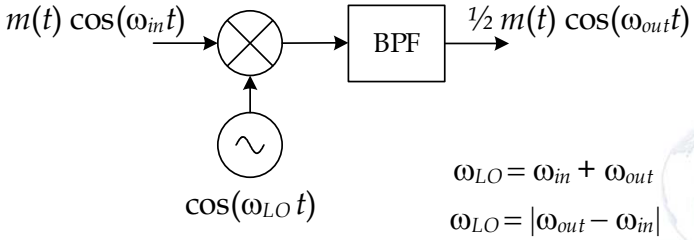


Be careful!

- A frequency converter is also commonly called a **mixer**, but do not confuse it with a multiplication device.
- A frequency converter is **not** a demodulator.
- A frequency converter is **not** a modulator.
- **Up converter** takes you from *low* input frequency to *high* output frequency.
- **Down converter** takes you from *high* input frequency to *low* output frequency.

Frequency Converter Hardware





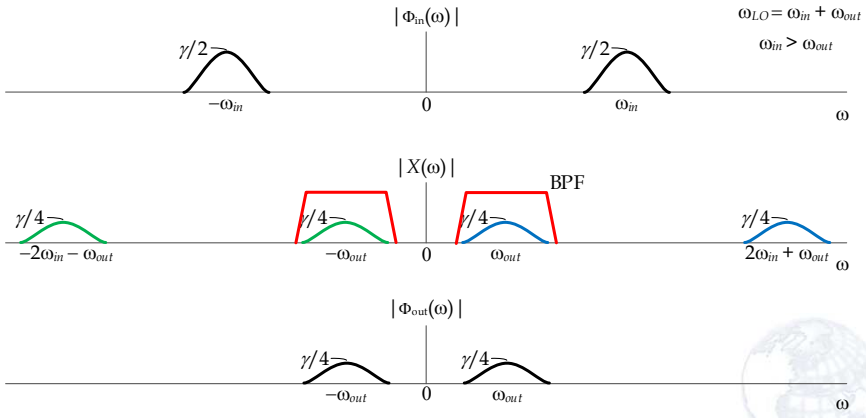
$\omega_{LO} = \omega_{in} + \omega_{out}$

$\omega_{LO} = |\omega_{out} - \omega_{in}|$

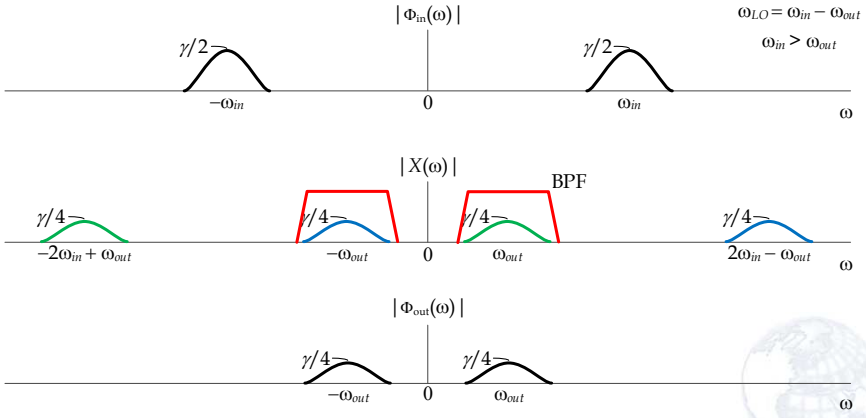
Examples

Input frequency f_{in}	Output frequency f_{out}	Device Type	L.O. frequency
300 MHz	100 MHz	Down converter (*sum*)	400 MHz
300 MHz	100 MHz	Down converter (*difference*)	200 MHz
100 MHz	300 MHz	Up converter (*sum*)	400 MHz
100 MHz	300 MHz	Up converter (*difference*)	200 MHz

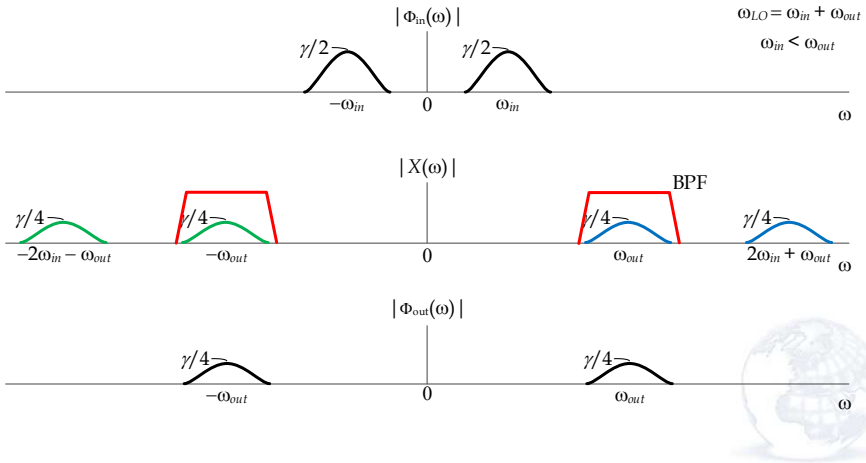
Frequency Converter
(Down Converter, Sum)



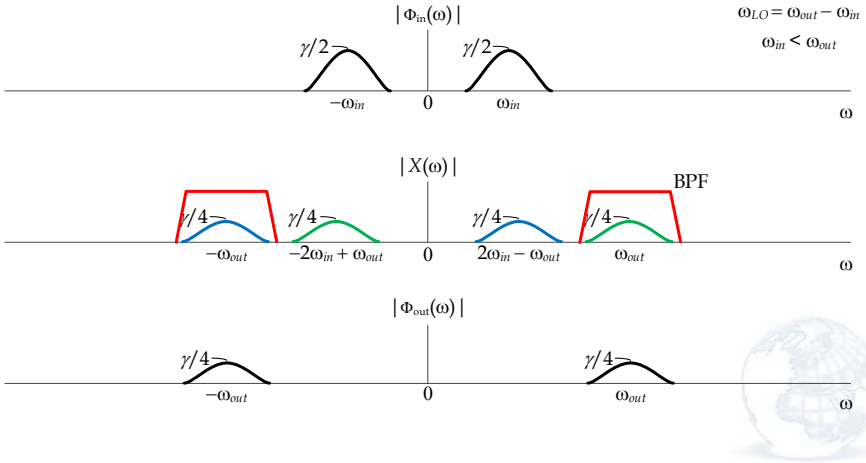
Frequency Converter
(Down Converter, Difference)



Frequency Converter
(Up Converter, Sum)



Frequency Converter
(Up Converter, Difference)



Homework 1

- Repeat the four cases above for SSB-SC (USB) input modulated signal:
  - Up converter, Sum
  - Up converter, Difference
  - Down converter, Sum
  - Down converter, Difference
- Find k in the output signal:

  $y(t) = k\,\varphi_{SSB-SC}(t)$
- Provide specifications for the BPF to be used.

Homework 2

- Does the frequency converter (mixer) work if you use $p(t)$ instead of cos ($\omega_{LO}t$)?
- If so, what is the necessary frequency(ies) for $p(t)$?
- Find k in the output signal:

  $y(t) = k\,m(t)\cos(\omega_{out}t)$
- Provide specifications for the BPF to be used.

