Lecture 5: Mixer (*Frequency Converter*)

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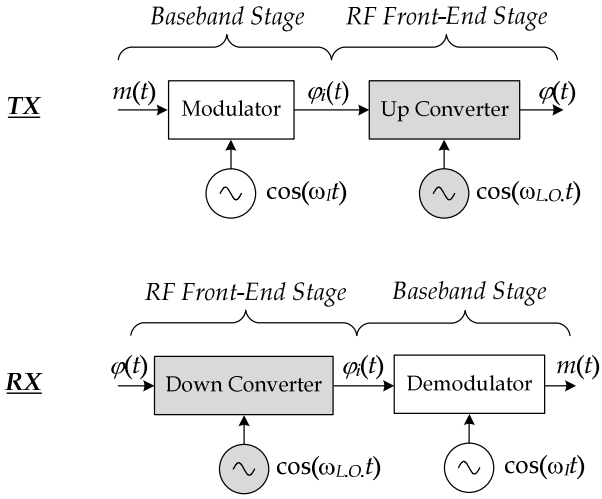
Meaning of Mixer

- 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.

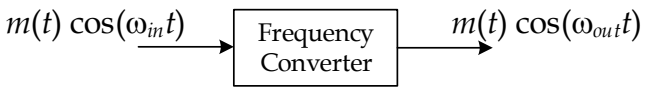
Heterodyne: Multiple Frequencies

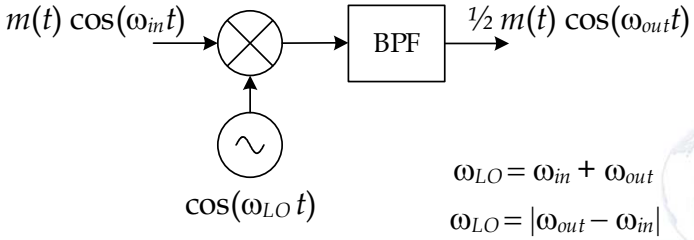
- Typical **transmitters** do not modulate immediately from baseband to carrier frequency ω_c. Rather, they modulate to an *intermediate frequency* ω_I, then an up-converter shifts the frequency to the higher frequency ω_c.
- Also, real-life **receivers** do not demodulate immediately from carrier frequency 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 later).

Frequency Conversion



Frequency Converter Hardware





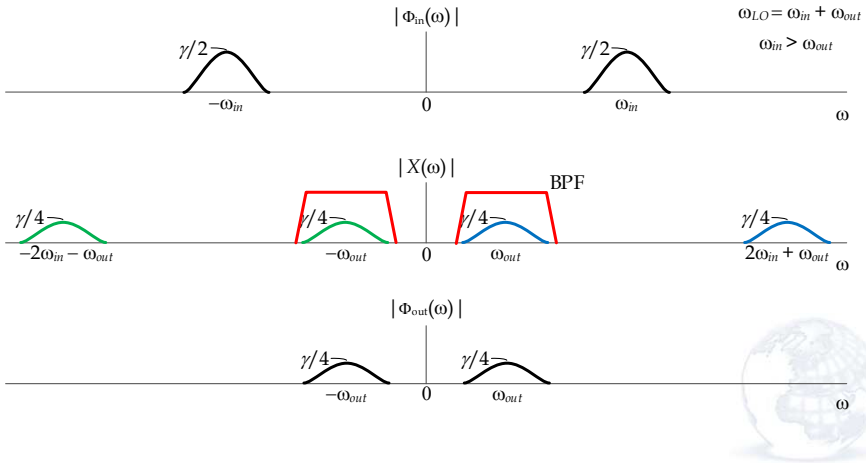
$\omega_{LO} = \omega_{in} + \omega_{out}$

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

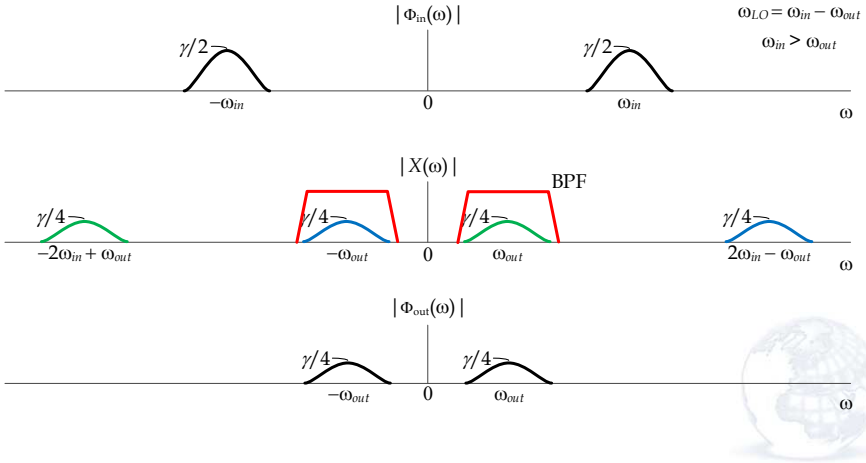
Examples

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

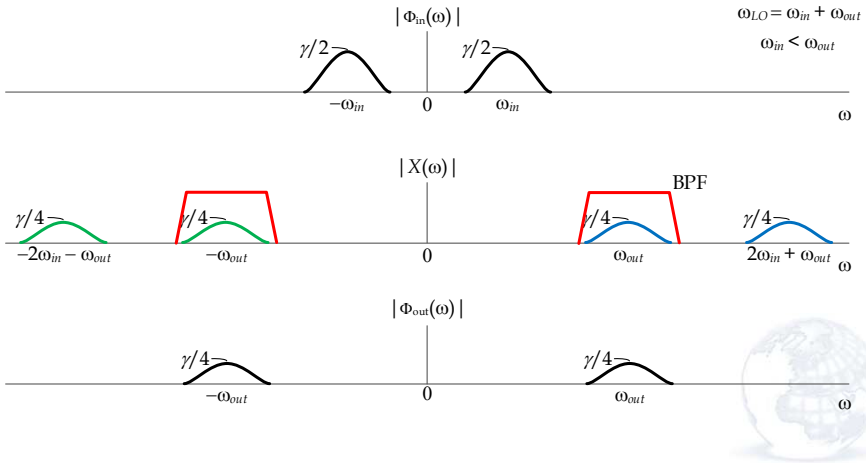
Frequency Converter
(Down Converter, Sum)



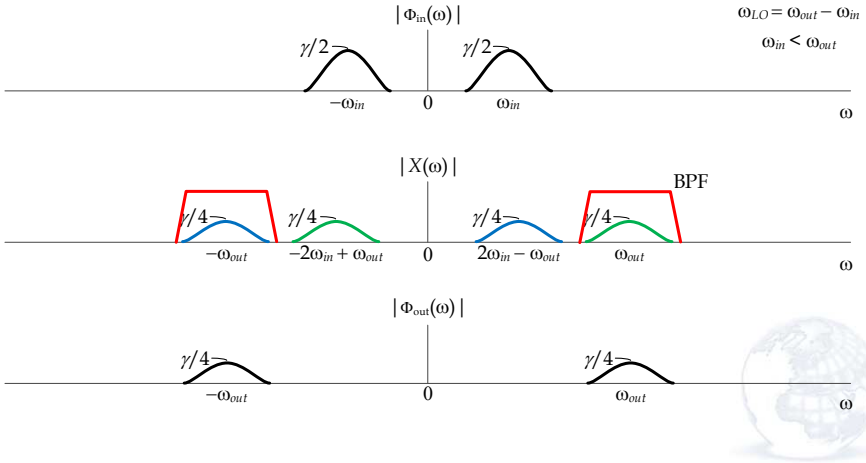
Frequency Converter
(Down Converter, Difference)



Frequency Converter
(Up Converter, Sum)



Frequency Converter
(Up Converter, Difference)



Homework 1

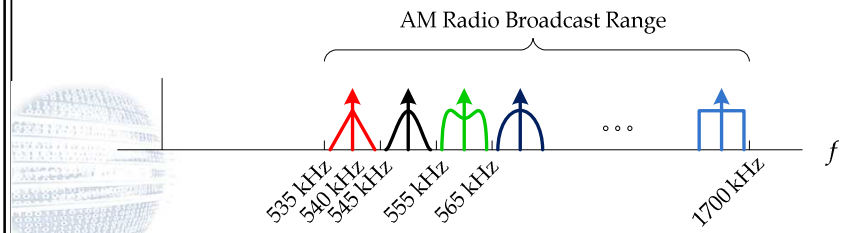
- Repeat the four cases above for SSB-SC (USB) input modulated signal:
  - Up converter, Sum
  - Up converter, Difference
  - Down converter, Sum
  - Down converter, Difference
- Find k in the output signal:
  $y(t) = k\,\varphi_{SSB-SC}(t)$
- Provide specifications for the BPF to be used.

Multiplexing: FDM

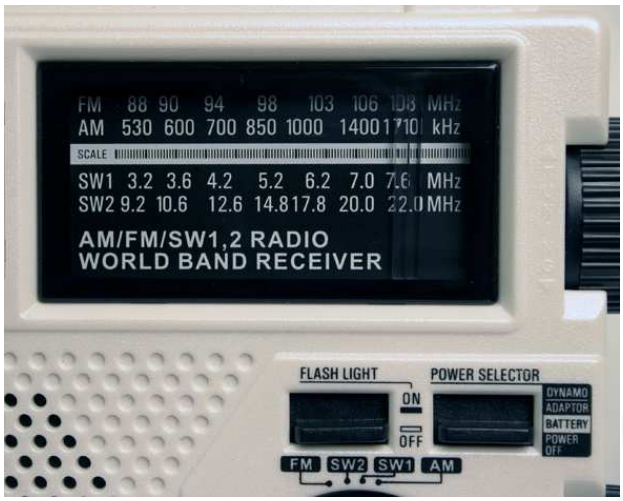
- Frequency Division Multiplexing (**FDM**) is a process that allows the transmission of several signals over the same channel at the same time.
- This is achieved by modulating the different signals on different carriers with different **carrier frequencies**.
- The receiver isolates one signal from the rest using a **tuneable BPF**.

AM Radio Broadcasting

- Each station is an AM modulation of human voice.
- FDM is used to multiplex signals on the air waves.
- **US:** Each station occupies a bandwidth of 10 kHz.
- **Europe:** Each station occupies a bandwidth of 9 kHz.



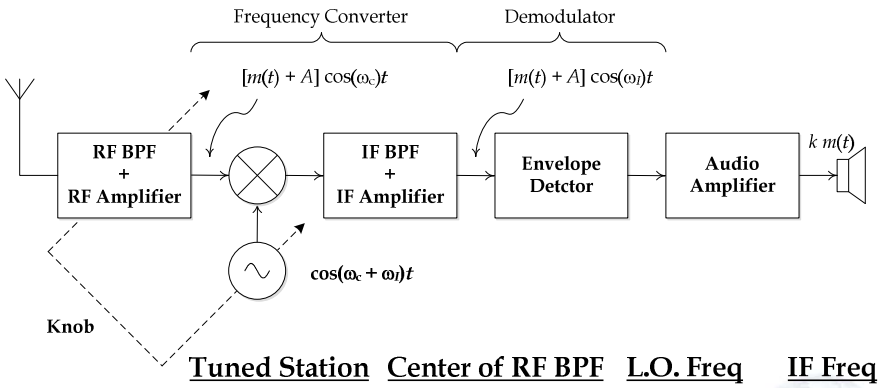
HW: Look at Your Radio Dial



The Superheterodyne Receiver

- Receivers in FDM system require a BPF.
- It is extremely difficult (*expensive*) to design highly selective (*narrowband*) filters at **high** center frequencies.
- This is specially true if the filter is **tuneable**.
- Solution: Use a two-stage filtering process, one of which at lower frequency.

AM Superheterodyne Receiver



Tuned Station	Center of RF BPF	L.O. Freq	IF Freq
1000 kHz	**1000 kHz**	**1455 kHz**	**455 kHz**
1020 kHz	1020 kHz	1475 kHz	455 kHz
1500 kHz	1500 kHz	1955 kHz	455 kHz

Ganged Capacitor

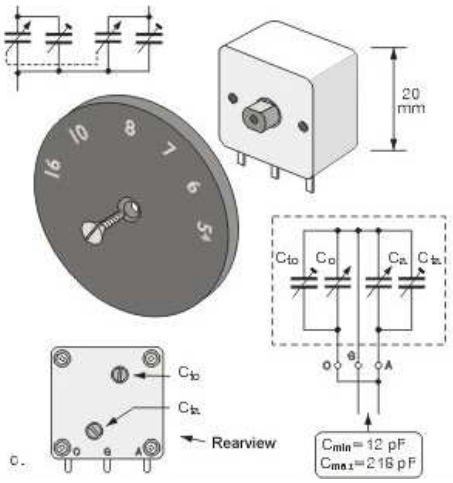


Image Station Problem

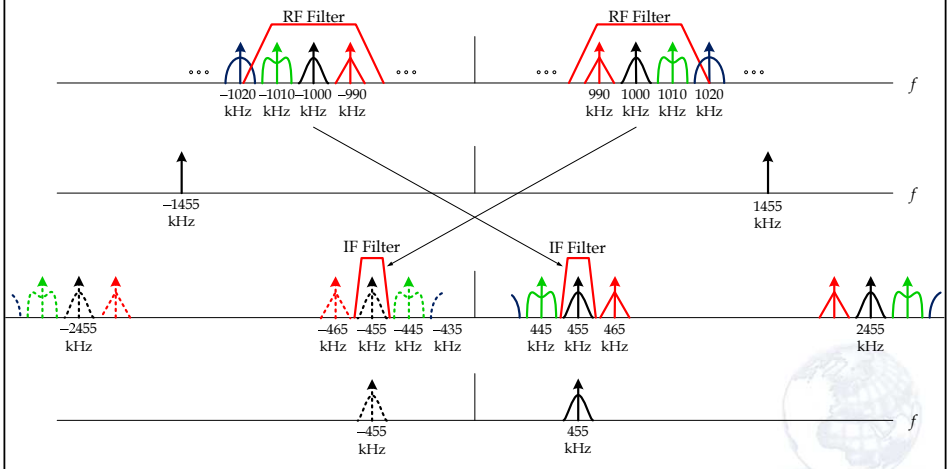
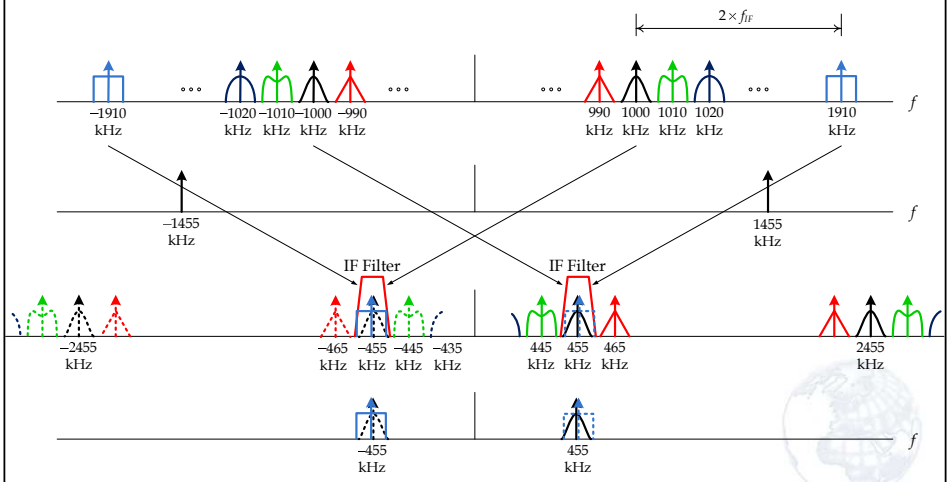


Image Station (*Part* 2)



Superheterodyne *Why*'s

- *Why* the RF Filter?
  - Eliminates the *image station*.
  - Reduces the amount (power) of noise that enters the receiver.
- *Why* the IF Stage (heterodyning)?
  - With its high-selectivity and lower price, the IF filter isolates the desired radio station from all others sent using FDM.
  - Since the IF frequency does not change with the tuned station, it is easier to design the E.D.

Superheterodyne *Why's*

- *Why* the sum, not difference?
- The sum (as opposed to the difference) in the receiver results in a smaller tuning range ratio, which requires a smaller tuning capacitor for the local oscillator.
- Hence, this solution is cheaper.

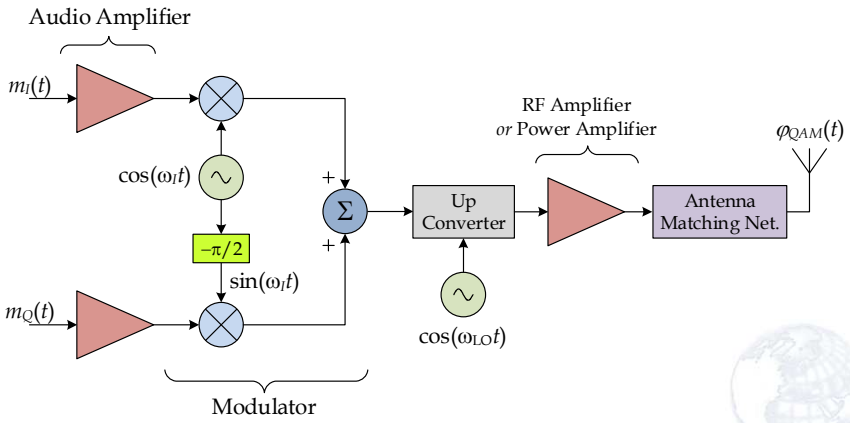
Homework

- Now design a superheterodyne receiver, but this time using the difference for L.O.:
  - If you want to listen to the station at 1000 kHz what settings should you choose for the RF BPF, the oscillator, and the IF BPF?
  - Repeat the same problem if you want to listen to the 1020 kHz and 1500 kHz stations.
  - What is the frequency of the image station if you are listening to the station at 1000 kHz?

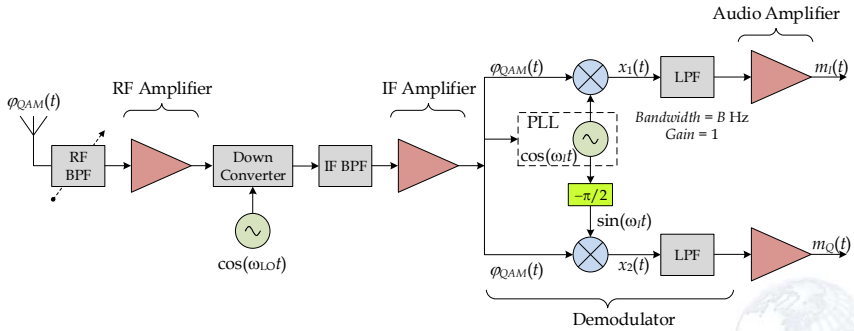
Superheterodyne *Everywhere!*

- The superheterodyne receiver is much more popular nowadays compared to the homodyne receiver.
- It is used in many communication systems including: FM Radio, Analog and Digital TV broadcasting, Cellular phones, WiMAX, Satellite and Microwave systems, GPS, etc.

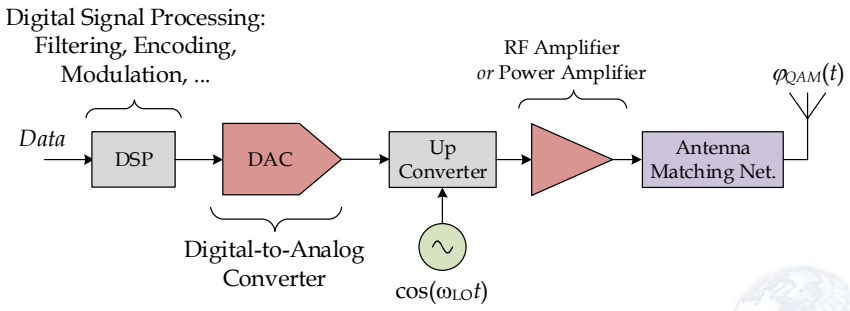
Full Transmitter



Full Receiver



Full Transmitter with DAC



Full Receiver with ADC