

Lecture 6: Mixer (Frequency Converter)

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EE423: Communication Electronics

Meaning of Mixer

- Frequency converter is commonly called a **mixer**, but do not confuse it with a multiplication device.
- Frequency converter is **not** a demodulator.
- 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.



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Heterodyne: Multiple Frequencies

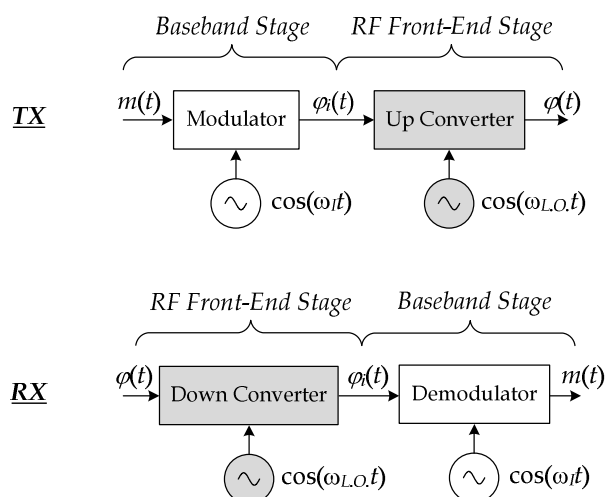
- Typical **transmitters** do not modulate immediately from baseband to carrier frequency ω_c . Rather, they modulate to an *intermediate frequency* ω_I , then an up-converter shifts the frequency to the higher frequency ω_c .
- Also, real-life **receivers** do not demodulate immediately from carrier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

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Frequency Conversion

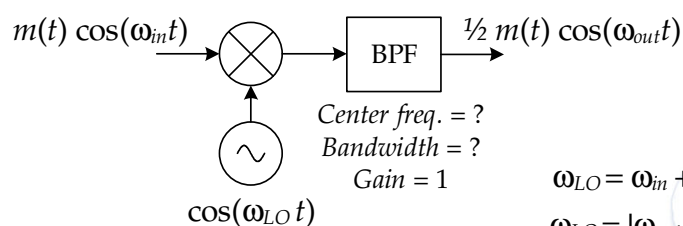
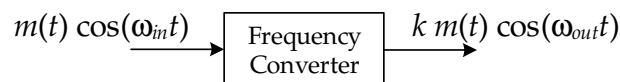


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Frequency Converter Hardware



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

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

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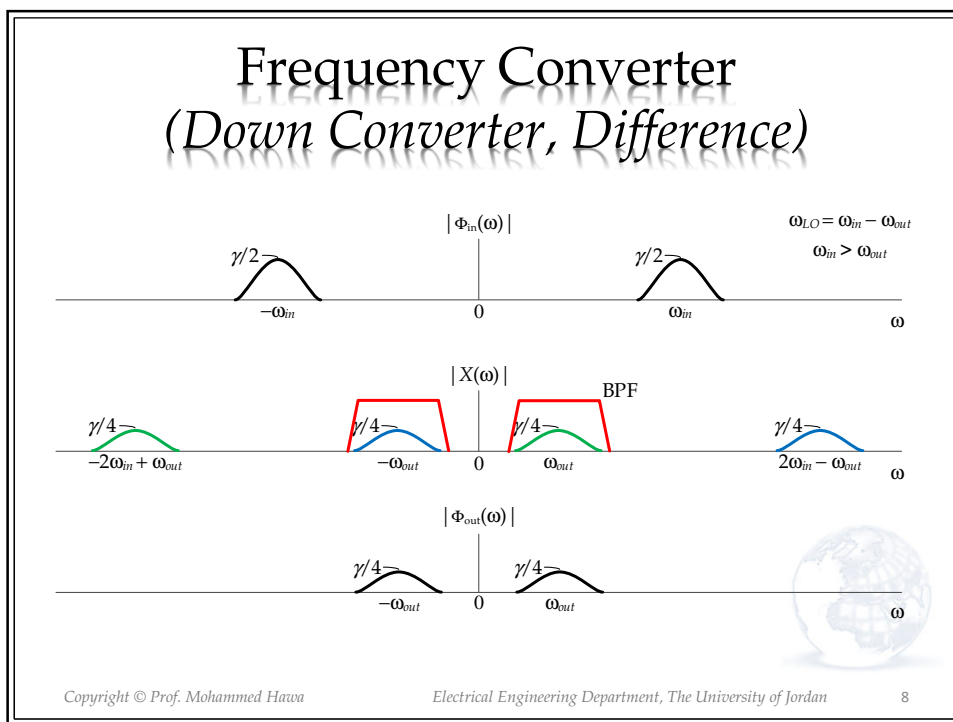
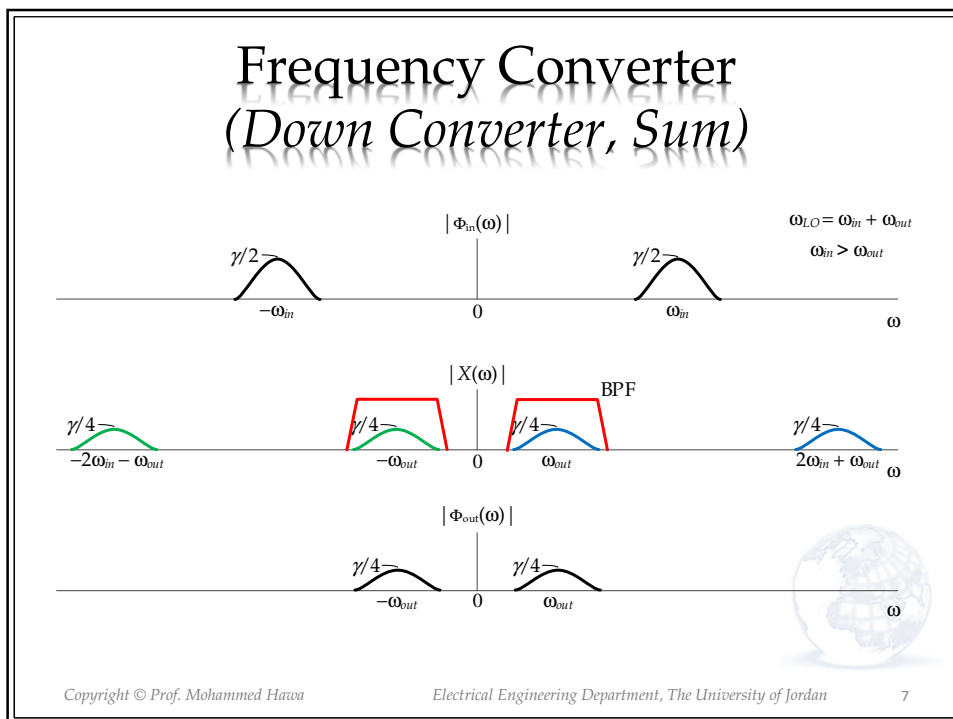
Examples

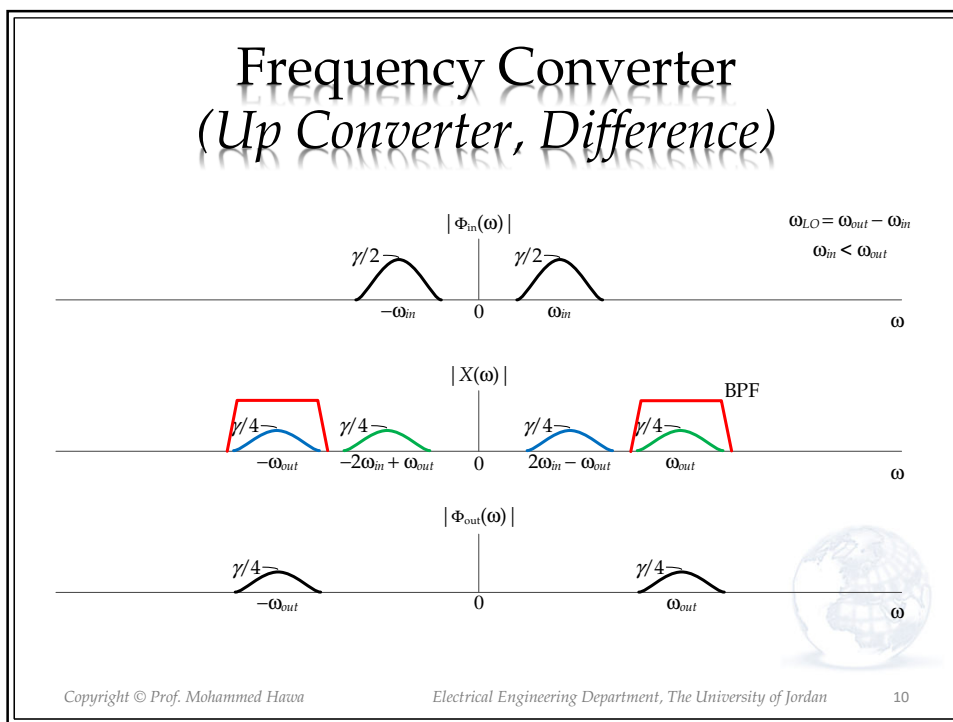
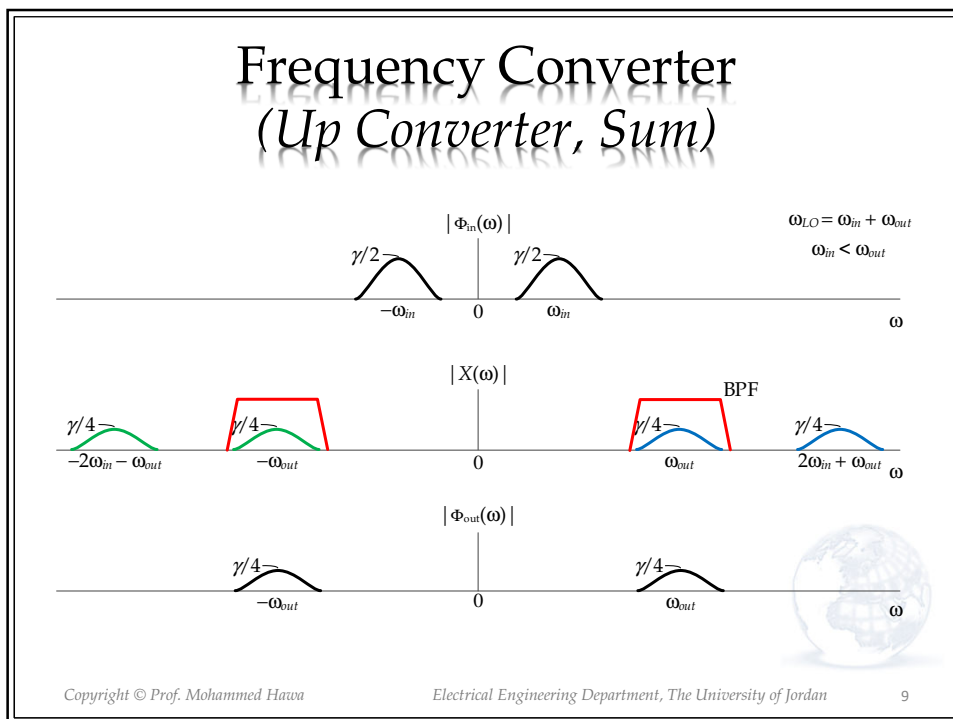
Input frequency f_{in}	Output frequency f_{out}	Device Type	L.O. frequency
300 MHz	100 MHz	Down converter (<i>sum</i>)	400 MHz
300 MHz	100 MHz	Down converter (<i>difference</i>)	200 MHz
100 MHz	300 MHz	Up converter (<i>sum</i>)	400 MHz
100 MHz	300 MHz	Up converter (<i>difference</i>)	200 MHz

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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.



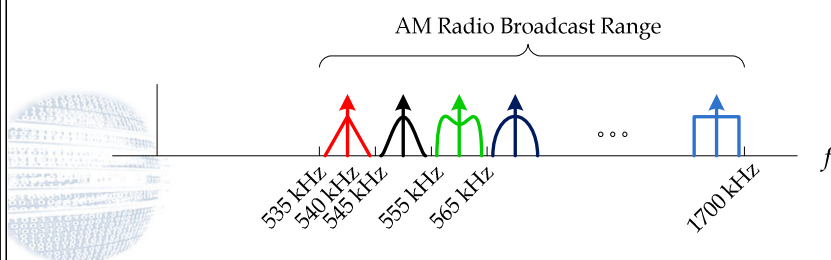
Multiplexing: FDM

- 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.

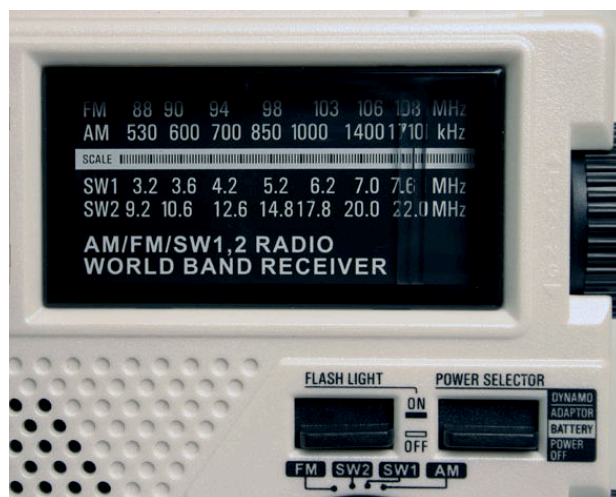


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HW: Look at Your Radio Dial



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Superheterodyne Receiver

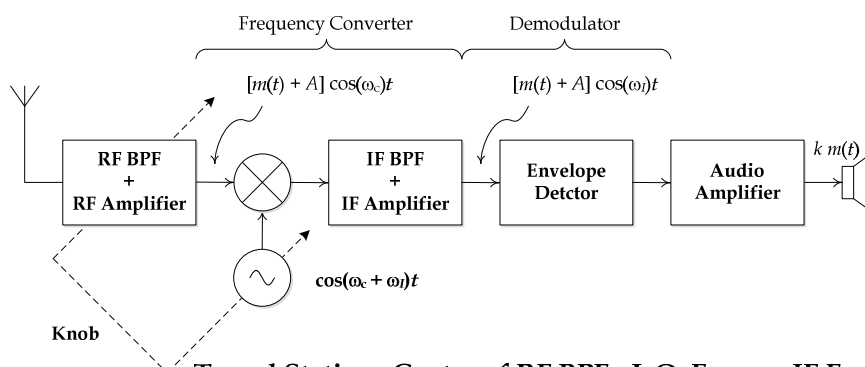
- Receivers in FDM system require a BPF.
- It is extremely difficult (*expensive*) to design highly selective (*narrowband*) filters at **high** center frequencies.
- This is specially true if the filter is **tunable**.
- Solution: Use a two-stage filtering process, one of which at lower frequency.

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AM Superheterodyne Receiver



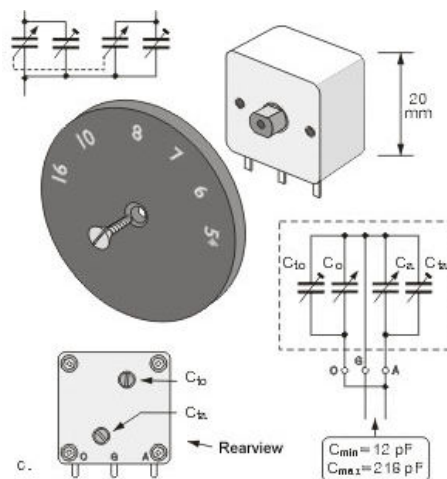
<u>Tuned Station</u>	<u>Center of RF BPF</u>	<u>L.O. Freq</u>	<u>IF Freq</u>
1000 kHz	1000 kHz	1455 kHz	455 kHz
1020 kHz	1020 kHz	1475 kHz	455 kHz
1500 kHz	1500 kHz	1955 kHz	455 kHz

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Ganged Capacitor

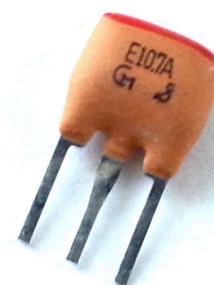
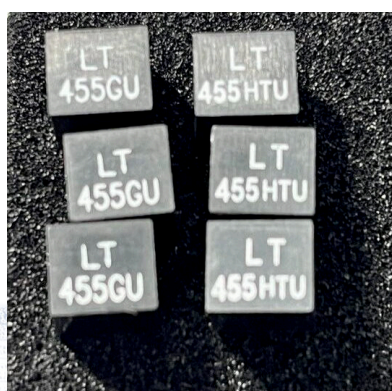


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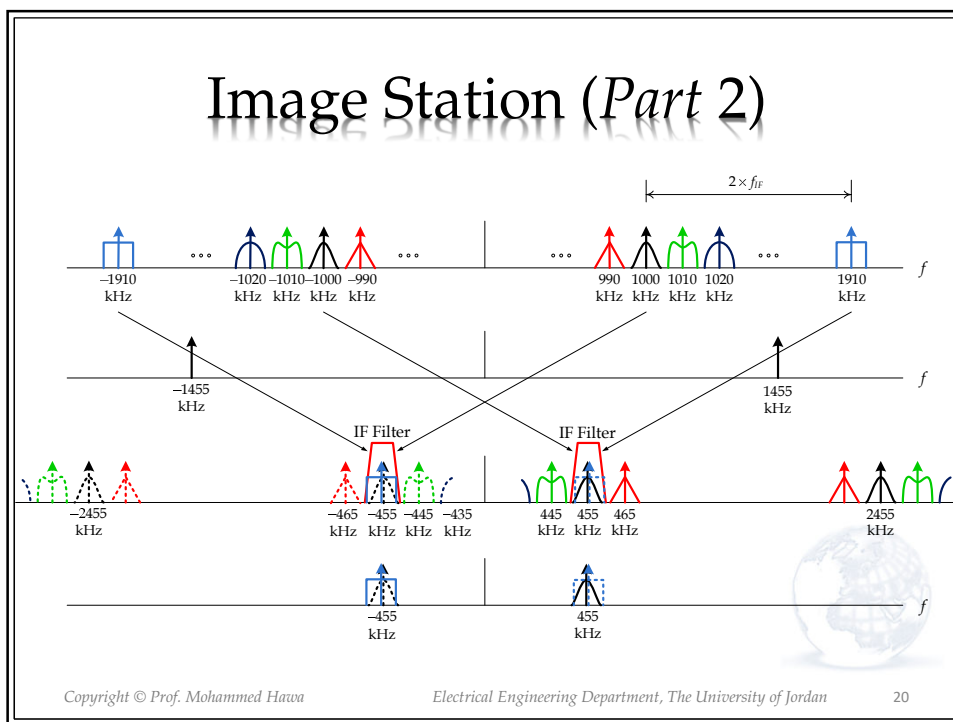
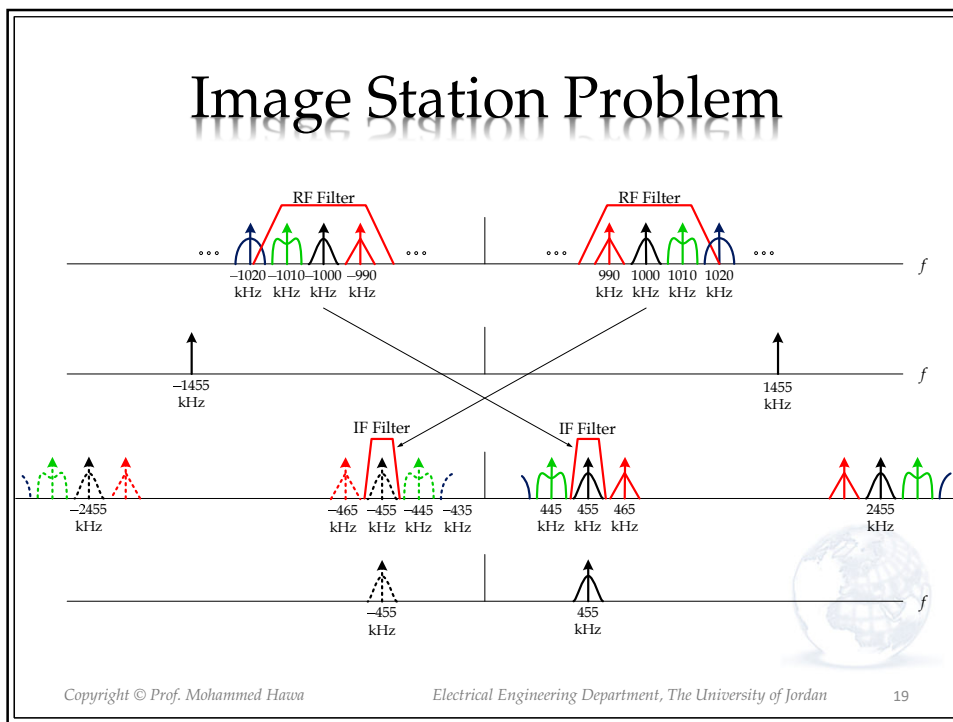
IF Ceramic Filters



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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?
 - What is the maximum allowable RF BPF bandwidth?



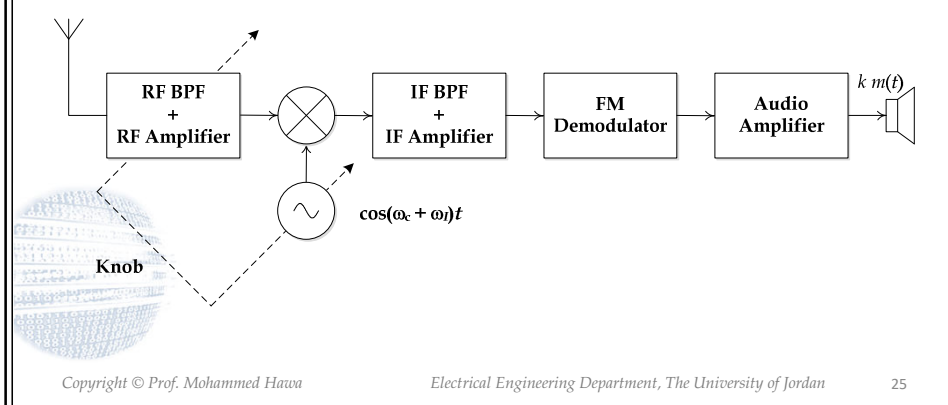
Superheterodyne *Everywhere!*

- The superheterodyne receiver is much more popular nowadays compared to homodyne receiver.
- It is used in many communication systems including: FM Radio, Analog and Digital TV broadcasting, Cellular phones, Satellite and Microwave systems, GPS, etc.
- Some popular IF frequencies:
 - AM radio receivers: 455 kHz
 - FM radio receivers: 10.7 MHz
 - Analogue television receivers: 45.75 MHz

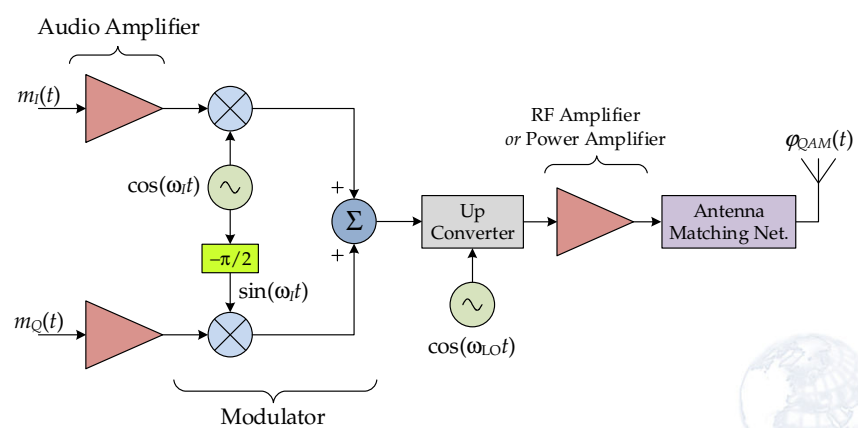


FM Superheterodyne Receiver

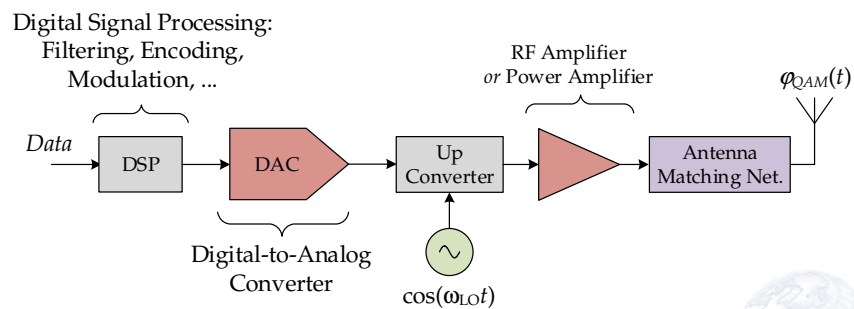
- IF frequency = 10.7 MHz
- L.O. frequency = 88 + 10.7 MHz to 108 + 10.7 MHz



Digital QAM Transmitter



QAM Transmitter with DAC



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```
>> t = [0:0.05:1]
      0   0.0500   0.1000   0.1500   0.2000   0.2500   0.3000
      0.3500   0.4000   0.4500   0.5000   0.5500   0.6000   0.6500
      0.7000   0.7500   0.8000   0.8500   0.9000   0.9500   1.0000

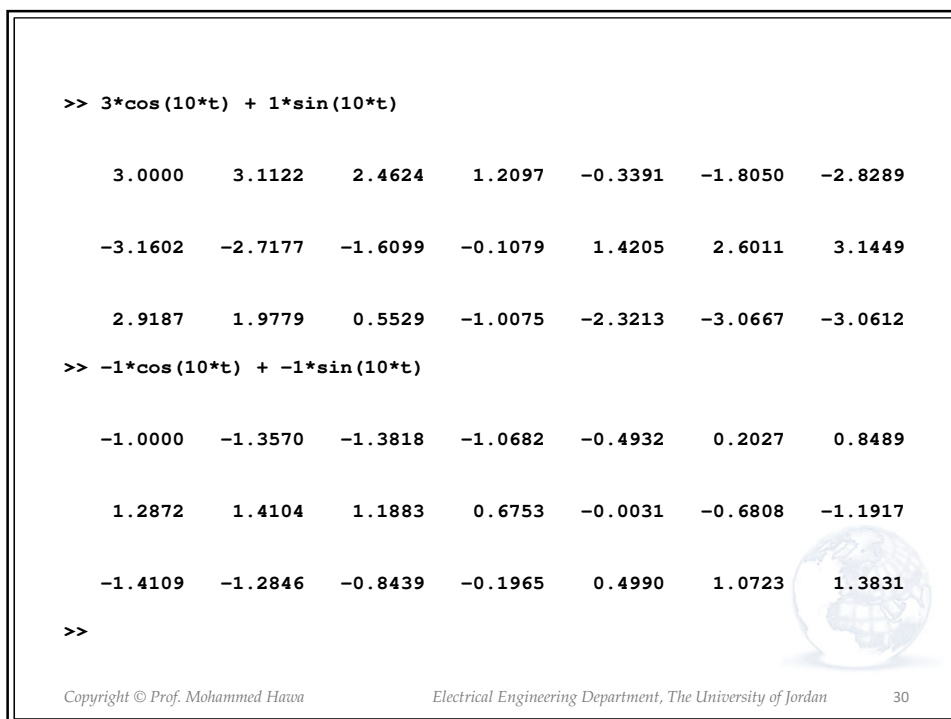
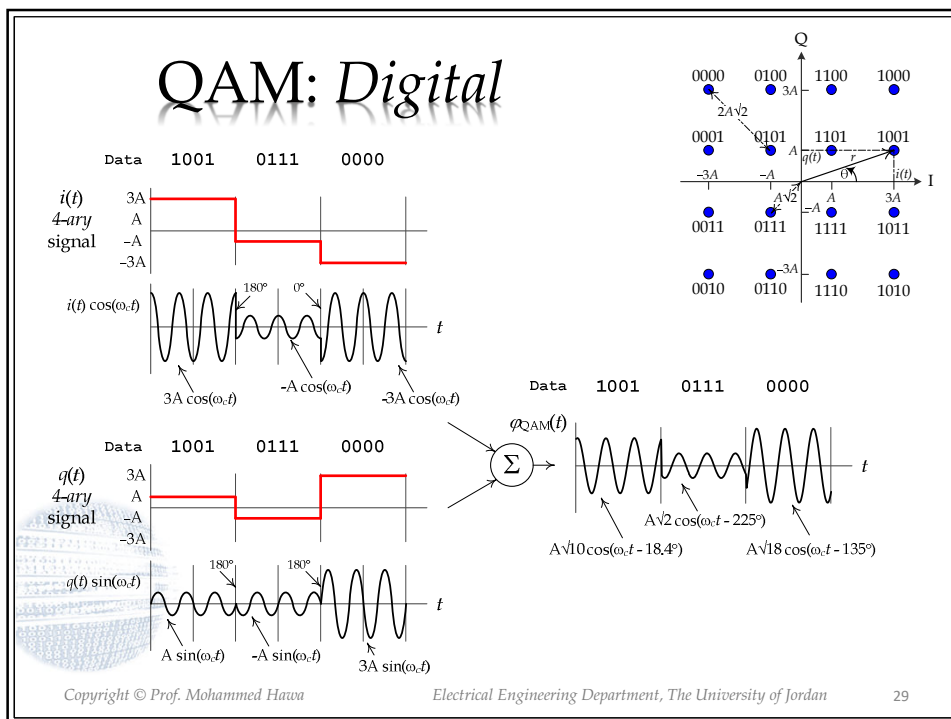
>> cos(10*t)
      1.0000   0.8776   0.5403   0.0707  -0.4161  -0.8011  -0.9900
     -0.9365  -0.6536  -0.2108   0.2837   0.7087   0.9602   0.9766
      0.7539   0.3466  -0.1455  -0.6020  -0.9111  -0.9972  -0.8391

>> sin(10*t)
      0   0.4794   0.8415   0.9975   0.9093   0.5985   0.1411
     -0.3508  -0.7568  -0.9775  -0.9589  -0.7055  -0.2794   0.2151
      0.6570   0.9380   0.9894   0.7985   0.4121  -0.0752  -0.5440
```

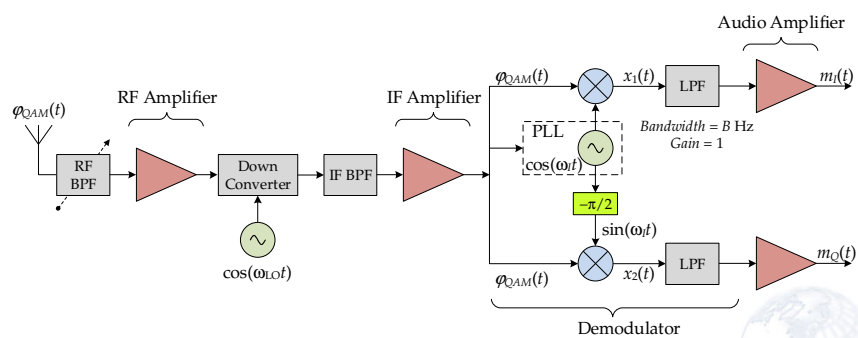
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Digital QAM Receiver

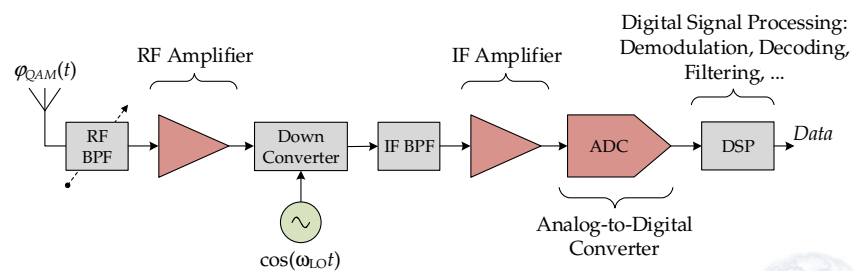


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QAM Receiver with ADC



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Satellite TV Broadcasting

- Satellite TV uses broadcast frequencies within the ranges (Uplink/Downlink):
- C band: 6/4 GHz
- Ku band: 14/10-12 GHz
- Ka band: 27-31/18-20 GHz

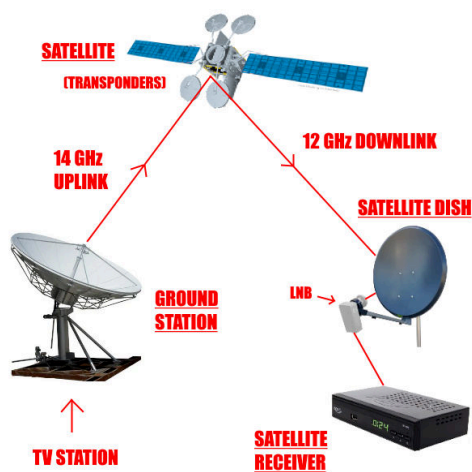


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Three Down Converters



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LNB Specifications



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Satellite Receiver Setup

Satellite	Frequency	P...	Symbol Rate	FEC	Type
	10719	V	27500	3/4	S
	10723	H	29900	3/4	S
Transponder	10758	V	27500	3/4	S
	10775	H	28000	3/4	S
DiSEqC	10796	V	27500	3/4	S
	10830	H	3333	3/4	S
Device	10834	V	27500	3/4	S
	10853	H	27500	3/4	S
Dish Alignment	10873	V	27500	3/4	S
	10892	H	27500	3/4	S
Mobile Settings	10911	V	27500	3/4	S
	10930	H	27500	3/4	S

IXE SOFT 12245,H,27500 Add Delete

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Values Not in the Exam

Supply		Block		Local oscillator frequency	Intermediate freq. range
Voltage	Tone	Polarization	Frequency band		
13 V	0 kHz	Vertical	10.70–11.70 GHz, low	9.75 GHz	950–1,950 MHz
18 V	0 kHz	Horizontal	10.70–11.70 GHz, low	9.75 GHz	950–1,950 MHz
13 V	22 kHz	Vertical	11.70–12.75 GHz, high	10.60 GHz	1,100–2,150 MHz
18 V	22 kHz	Horizontal	11.70–12.75 GHz, high	10.60 GHz	1,100–2,150 MHz

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Mixer Performance Parameters

- The frequency converter design can apply tradeoffs for different performance parameters:
- Conversion loss (*opposite* of gain).
- Image rejection ratio.
- Noise figure.
- Harmonic content: Mixing is sometimes achieved using nonlinear devices and/or processes, thus generating extra undesired harmonics (tones), not just the ones of interest.

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