Module 7

Modulation and Transceivers

References

- *Canadian Amateur Radio Basic Qualification Study Guide* (8th Ed.), Chapters 12 and 13

Modulation

Chapter 13

Definition

- modulation is the process of varying one or more properties of a high-frequency periodic waveform, called the carrier signal, with a modulating signal which typically contains information to be transmitted.
- modulation is the process of conveying a message signal, for example a digital bit stream or an analog audio signal, inside another signal that can be physically transmitted.

Terms

- changing the carrier
  - frequency
  - phase
  - amplitude
- Modulate
- Demodulation or detection
  - recovering the intelligence

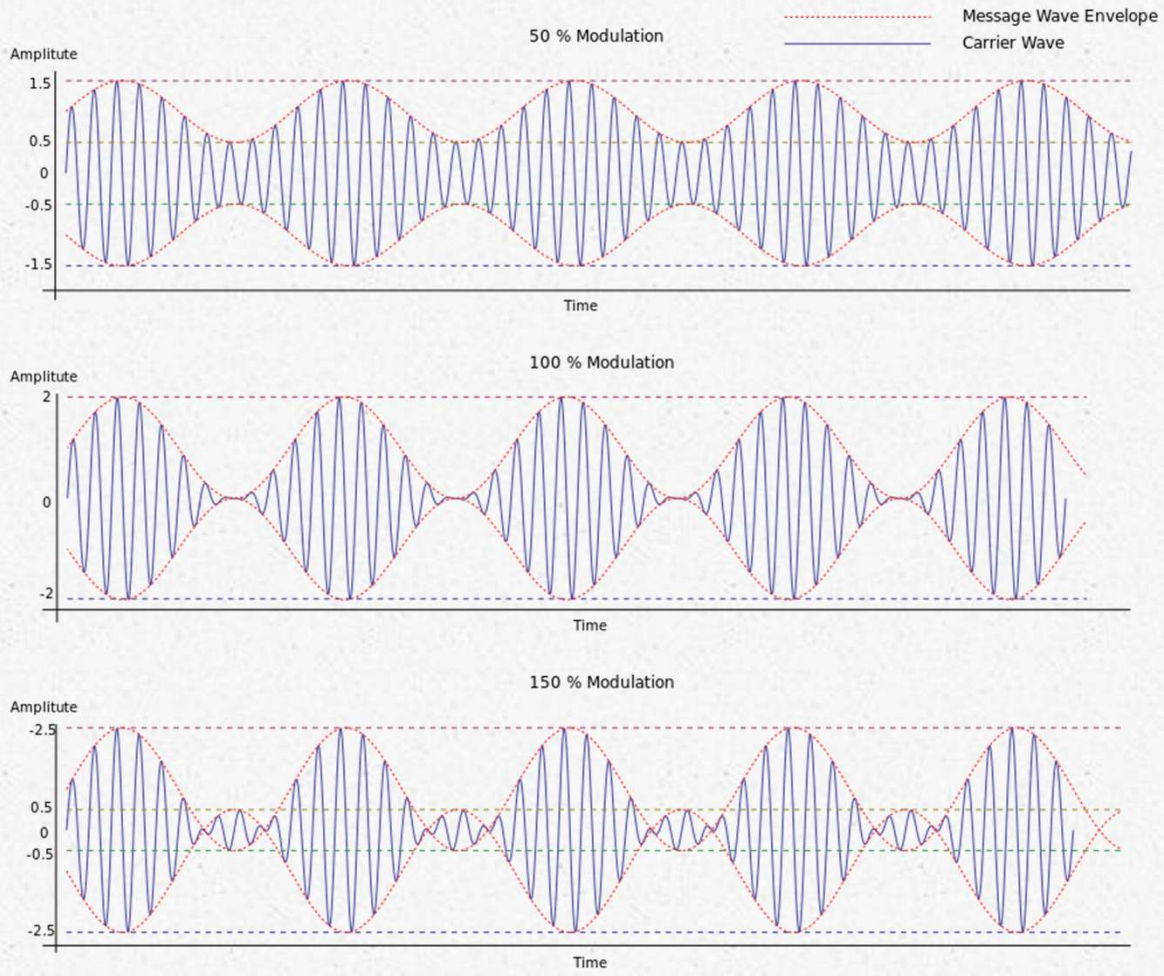
Telegraphy (CW)

- simplest method
- turn carrier on and off (Continuous Wave or CW)
- International Morse Code
- Advantages
  - 150-500 Hz v. 3kHz for SSB or 6 kHz for AM
  - unilingual (i.e. no accent)
  - CW can get through when voice cannot

Amplitude Modulation (AM)

- Broadcast AM
- change instantaneous power of carrier in time with the modulating signal
- e.g. whistle 1kHz tone into microphone it gets stronger and weaker (sine)
- We want to vary voltage on the final amplifier of the transmitter so it varies in accordance with the 1 kHz tone
- (remember transistors…)
- we end up with a modulation envelope

AM


Message Wave Envelope
Carrier Wave
50 % Modulation
Amplitute
1.5
0.5
0
-0.5
-1.5
Time
100 % Modulation
Amplitute
2
0
-2
Time
150 % Modulation
Amplitute
-2.5
0.5
0
-0.5
-2.5
Time

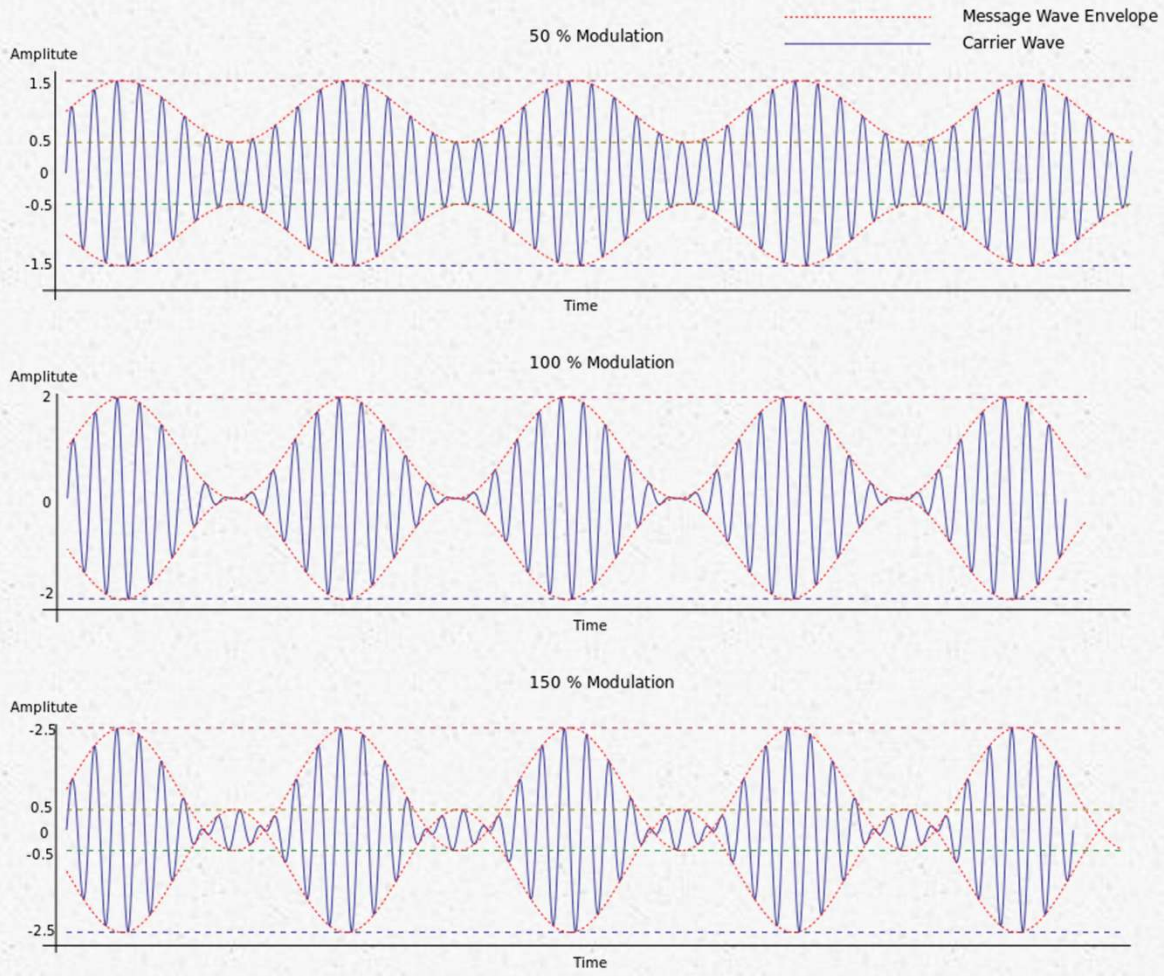
AM

- instantaneous power can be calculated from signal supplied to antenna transmission line – **peak envelope power** = average power delivered to the antenna transmission line during one RF cycle, at the crest of the modulation envelope under normal operating conditions - **PEP**

AM

- if 100% modulated signal reaches zero peaks on negative peaks of modulating signal – no interference or distortion
- if negative signal were to increase then carrier instantly cuts off causing distortion and channel interference – over modulation
- super modulation can also occur – distortion
- recall amateur stations limited to 100% modulation

AM


Message Wave Envelope
Carrier Wave
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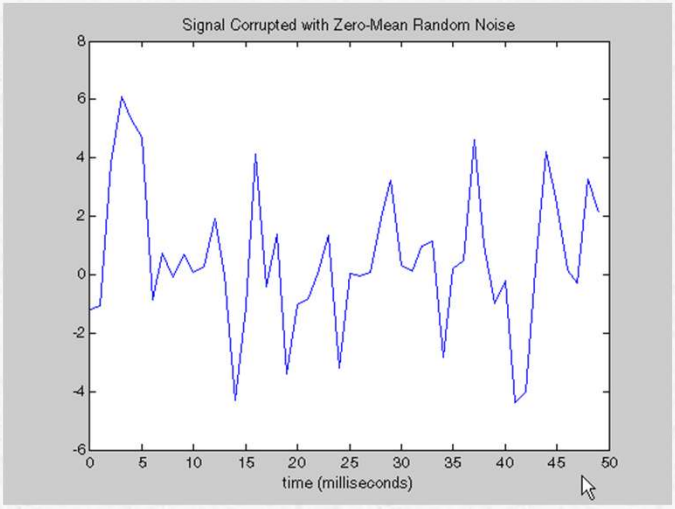
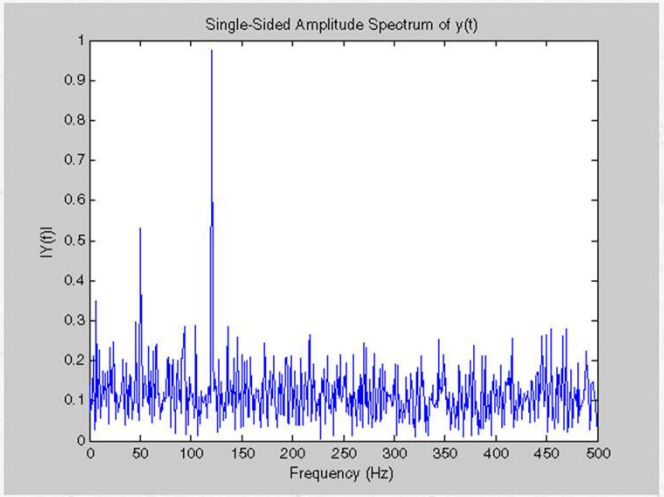
0.5
0
-0.5
-2.5
Time

Time Domain v. Frequency Domain





FOURIER TRANSFORM

$$X(k) = \sum_{j=1}^{N} x(j)\omega_N^{(j-1)(k-1)}$$

$$x(j) = (1/N)\sum_{k=1}^{N} X(k)\omega_N^{-(j-1)(k-1)}$$

AM

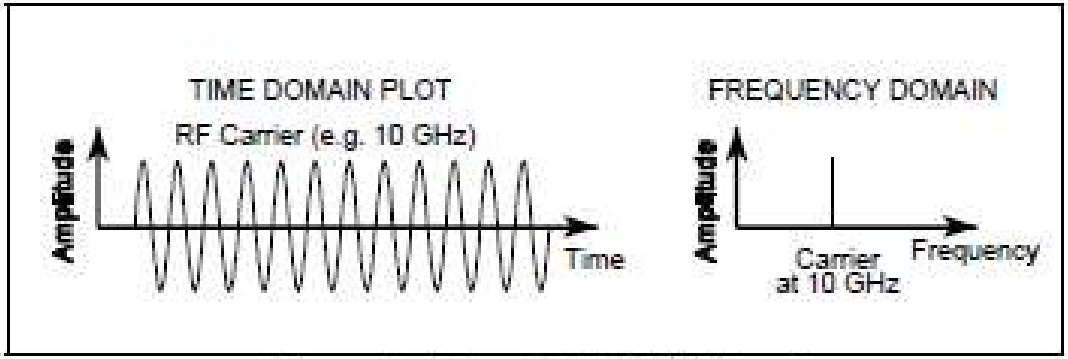


Figure 1. Unmodulated RF Signal

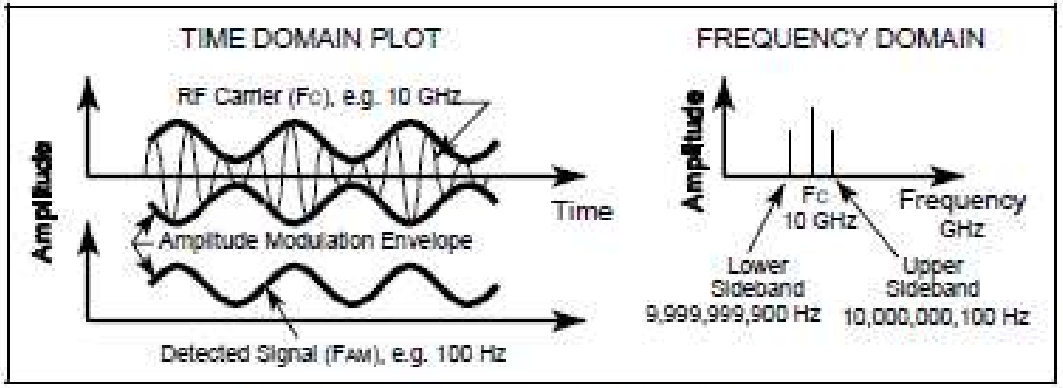
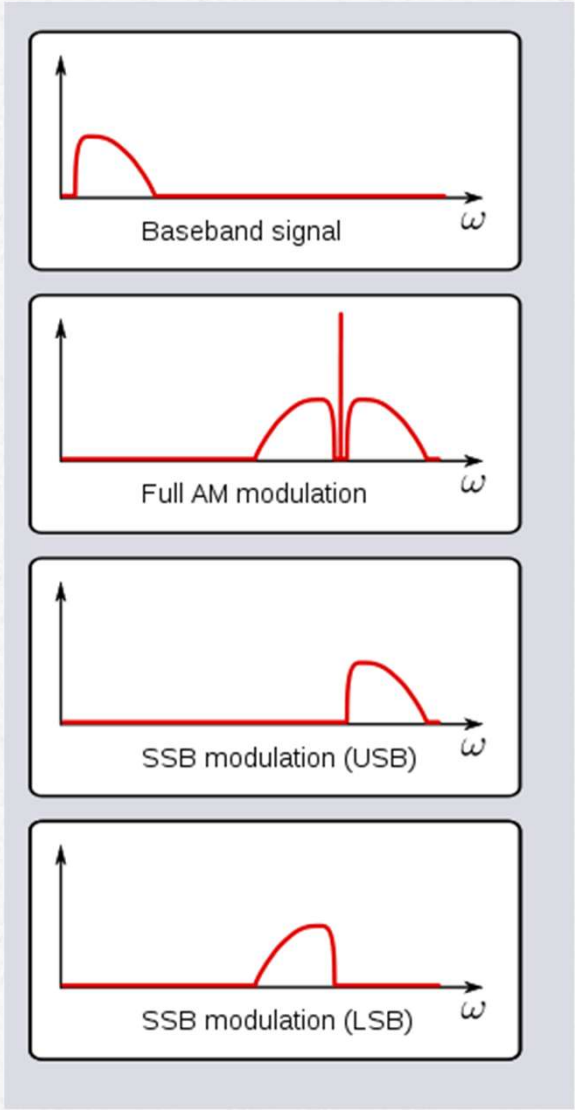


Figure 3. Sinewave Modulated RF Signal

AM

- Sidebands
  - sum and difference of carrier and modulating frequencies
  - lower and upper
- Carrier
- Mixing
- Power
  - carrier 10 GHz of 1 kW modulated by 100 Hz
  - Carrier is still 1 kW but each sideband is 250 W (i.e. ¼ power in the carrier)

SSB



- If we suppress carrier DSSC (DSB)
- If we suppress carrier and lower sideband, USB
- if we suppress carrier and upper sideband, LSB
- 3kHz v. 6 kHz (where does 3 kHz come from?)
- SSB standard telephone transmission on Amateur HF

Frequency Modulation (FM)

- FM v. PM
- Amount frequency raised or lowered from its normal amount is its deviation
- Under-deviated sounds thin and weak/over deviation sounds unnaturally loud and distorted

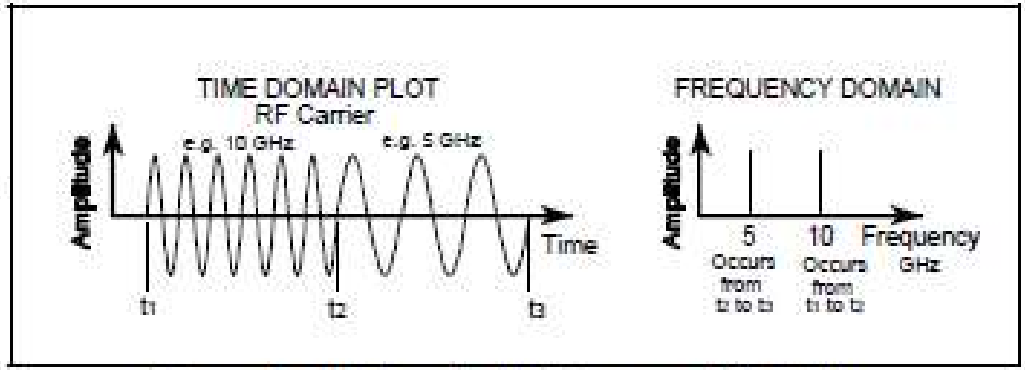
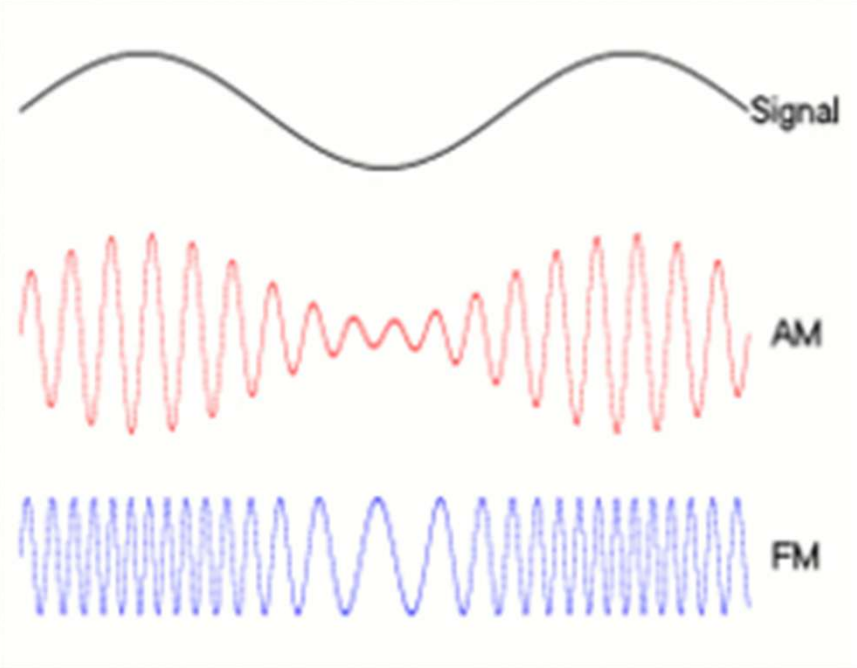
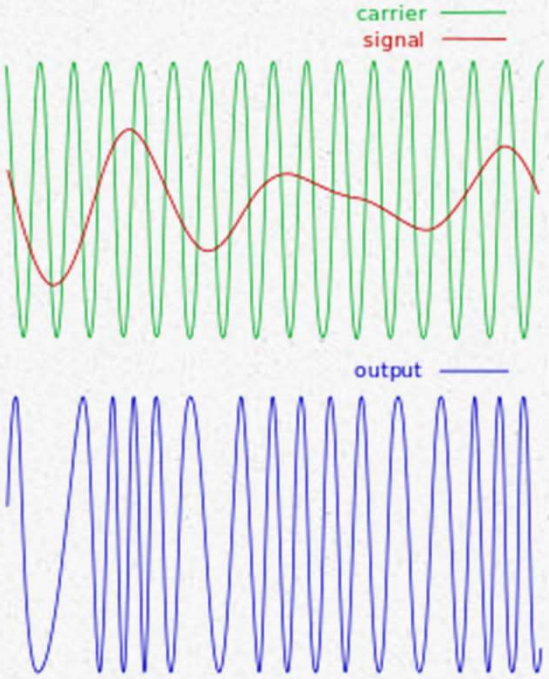


Figure 2. RF Signal with Frequency Modulation

FM





FM

- VHF and HF use NBFM (max dev of 5 kHz) (commercial FM is over 50 kHz)
- bandwidth (limited)
- narrowest bandwidth is CW at 100-250 Hz (according to book – actually PSK 31 is 31.25 Hz)
- AM occupies 6 kHz (recall 30 Hz to 3kHz)
- SSB deletes one sideband and carrier 2.7kHz

FM Bessel Functions (Power in sidebands)

Modulation index	Sideband																
	Carrier	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
0.00	1.00																
0.25	0.98	0.12															
0.5	0.94	0.24	0.03														
1.0	0.77	0.44	0.11	0.02													
1.5	0.51	0.56	0.23	0.06	0.01												
2.0	0.22	0.58	0.35	0.13	0.03												
2.41	0	0.52	0.43	0.20	0.06	0.02											
2.5	−0.05	0.50	0.45	0.22	0.07	0.02	0.01										
3.0	−0.26	0.34	0.49	0.31	0.13	0.04	0.01										
4.0	−0.40	−0.07	0.36	0.43	0.28	0.13	0.05	0.02									
5.0	−0.18	−0.33	0.05	0.36	0.39	0.26	0.13	0.05	0.02								
5.53	0	−0.34	−0.13	0.25	0.40	0.32	0.19	0.09	0.03	0.01							
6.0	0.15	−0.28	−0.24	0.11	0.36	0.36	0.25	0.13	0.06	0.02							
7.0	0.30	0.00	−0.30	−0.17	0.16	0.35	0.34	0.23	0.13	0.06	0.02						
8.0	0.17	0.23	−0.11	−0.29	−0.10	0.19	0.34	0.32	0.22	0.13	0.06	0.03					
8.65	0	0.27	0.06	−0.24	−0.23	0.03	0.26	0.34	0.28	0.18	0.10	0.05	0.02				
9.0	−0.09	0.25	0.14	−0.18	−0.27	−0.06	0.20	0.33	0.31	0.21	0.12	0.06	0.03	0.01			
10.0	−0.25	0.04	0.25	0.06	−0.22	−0.23	−0.01	0.22	0.32	0.29	0.21	0.12	0.06	0.03	0.01		
12.0	0.05	−0.22	−0.08	0.20	0.18	−0.07	−0.24	−0.17	0.05	0.23	0.30	0.27	0.20	0.12	0.07	0.03	0.01

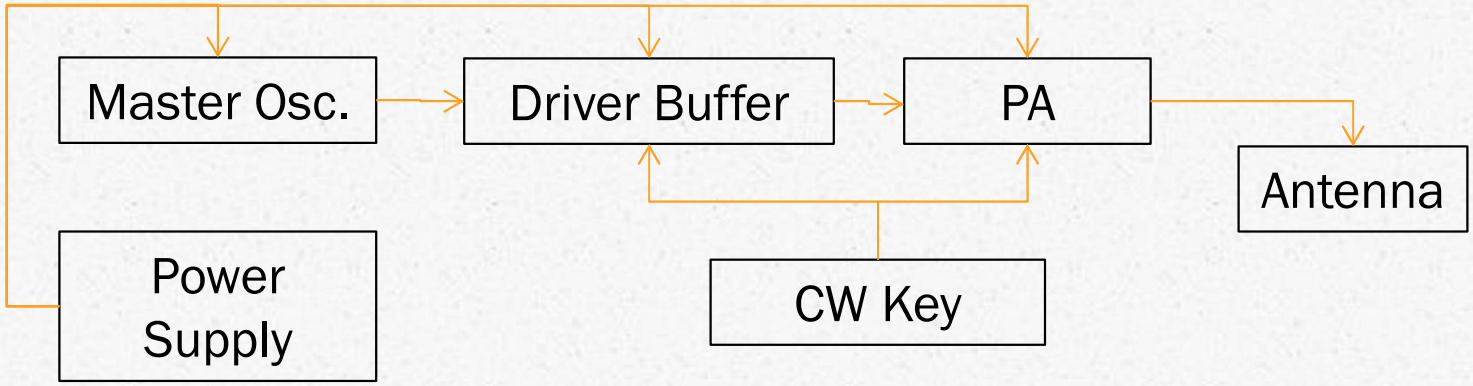
FM

- max dev of carrier from rest frequency and maximum frequency allowed to modulate it determine the bandwidth – Bessel functions
- bandwidth occupied > deviation
- HAM channels are 15 kHz wide to accommodate 5 kHz deviation signal and 3kHz max modulating frequency
- Bandwidth so large, exceeds permissible HF bandwidth except in 10 m (bandwidth permitted is 20 kHz)
- FM permitted above 29.5 MHz on FM portion of 10 M band

Transmitters

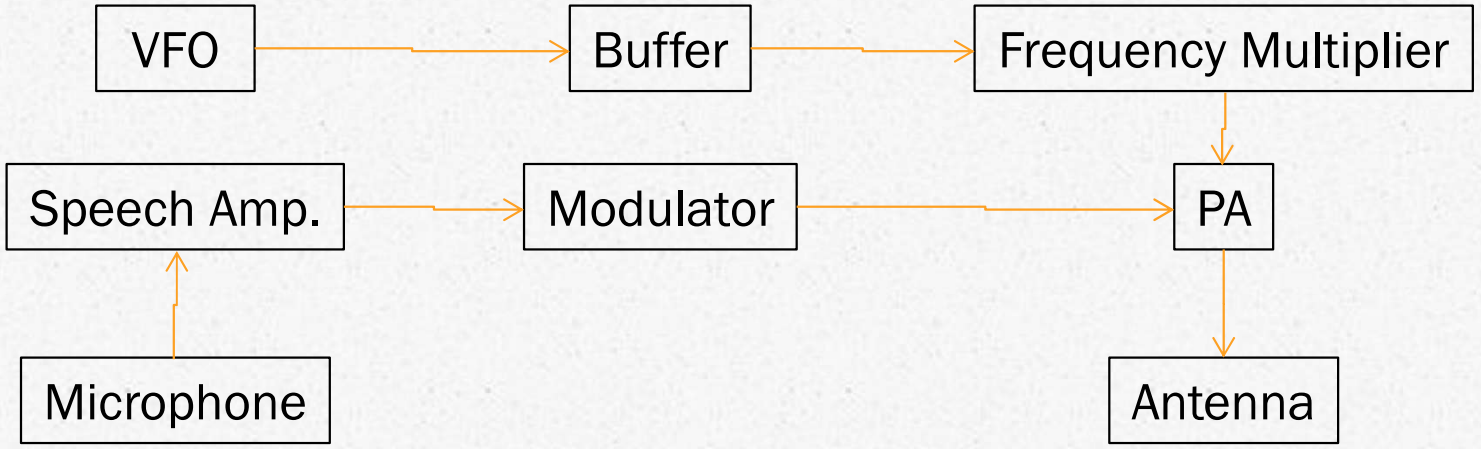
- generate RF energy at desired frequency
- free of distortion, transmitted at specified frequency and not change frequency
- if frequency changes with time, drift (crystals)
- controls RF waves using microphone or key so as to superimpose or modulate RF waves
- increase RF strength if necessary (RF amp)
- radiate RF via antenna
- not interfere with other services

CW Transmitter



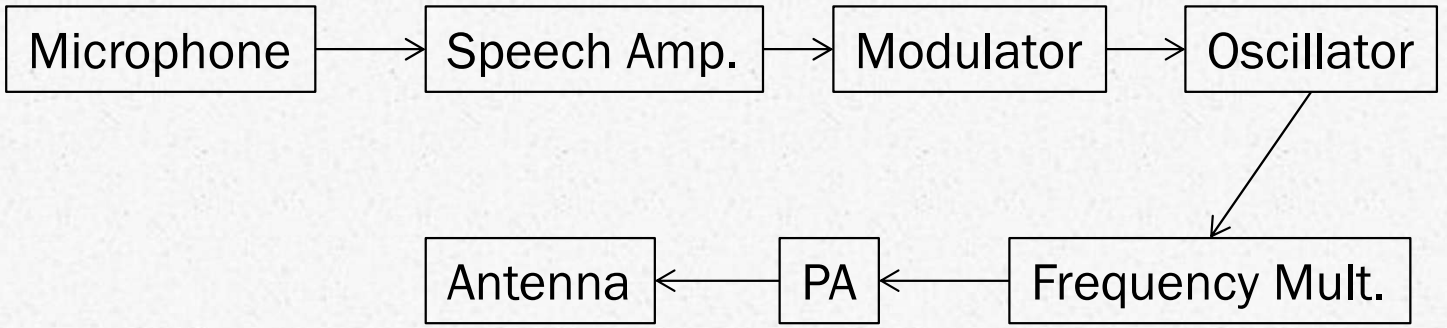
- Oscillator – stable, no drift PLL, Freq Syn, crystal
- Driver Buffer – isolates Mast. Osc. from PA
- PA – final amplifier
- Key
- Power 13.8 VDC etc.
- Antenna

AM Transmitter



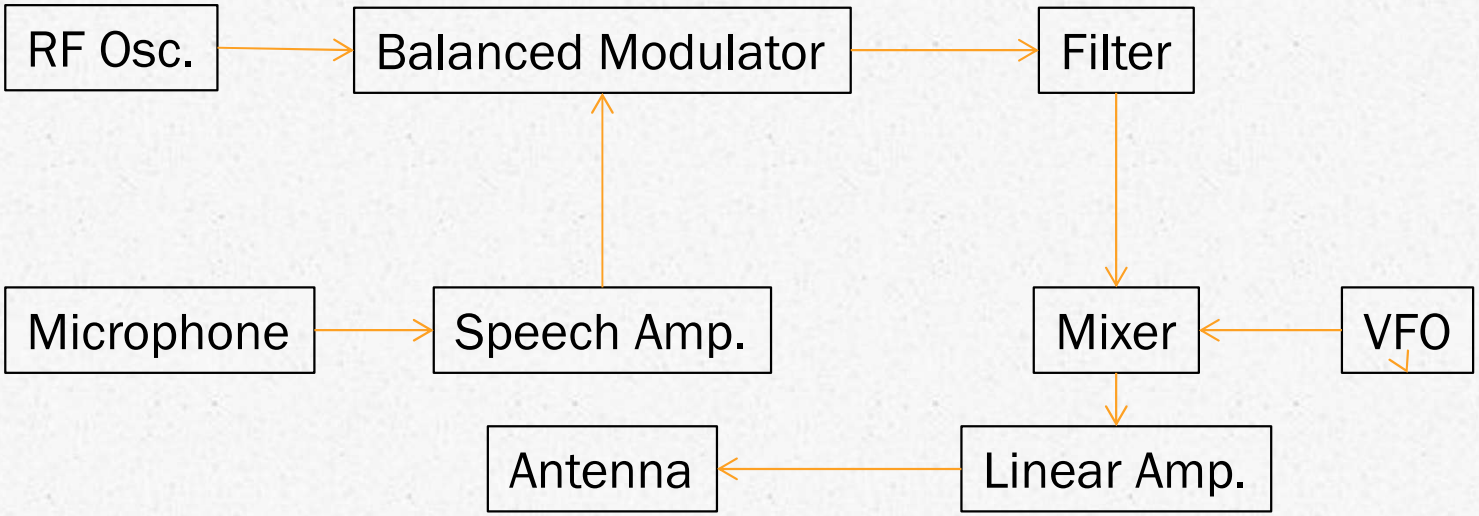
- VFO – can be used in CW transmitter or any
- Buffer – isolates VFO from frequency mult.
- Frequency Mult –
- PA
- Antenna
- Note role of microphone and speech amplifier

FM Transmitter



- as per AM
- frequency or phase multiplier
- if oscillator puts out 12.245 MHz it can be multiplied by 12 to get 146.940 MHz
- Power Supply missing but necessary

SSB Transmitter



- balanced modulator suppresses carrier and passes only 2 AM sidebands
- filter removes one of the sidebands (more often the modulator does this through DSP chip)
- PA is a linear amplifier – increases power of AM RF w/o distortion (linear)
- Antenna

Digital Transmitters

- Most HAM equipment creates analog image of digital signal and transmits AM or FM
- asynchronous v. synchronous methods
- RTTY – terminal unit – 2 tone signal
- FEC
- Terminal node controller (TNC)
- Modem
- FSK, AFSK
- PSK (00, 01, 10 and 11)
- Baud = no. of discrete changes in carrier in a second

Transmit and Receive Switches

- Transmit and Receive Switch
- Antenna changeover switch
- separate Xmtr and Rcvr
- use of diodes (Fig. 13-8)
- Transmitter Power
  - Max power is 250 W for Basic Qualification
  - Max power is 1 kW for Advanced Qualification
  - applied to final stage of amp
    - at anode of vacuum tube
    - at collector of power transistor in solid state amp.
    - NOTE: 250 W DC = 560 W PEP

Receivers

Chapter 14

Overview

- antenna – captures RF wave
- desired frequency must be selected from all EM waves antenna captures
- selected signal weak – amplified
- information carried by wave must be recovered
- audio signal to be amplified
- audio signal converted into sound waves by electromechanical device

Terminology

- characterized by ability to separate and decode/demodulate signals – demodulator
- Sensitivity
  - min signal level receiver can detect μV in HF and fractions μV in VHF
- Selectivity
  - ability to separate two closely spaced signals
- Cross Modulation
  - incoming sigs overload front end – ATT switch
- Images
  - signals on a different frequency to that tuned by received anyway – internal – should be rejected
- Stability
  - ability to tune frequency and remain at it for a period of time - drift

Noise

- QRN v. QRM
- noise floor
- QRN
  - lightening – noise limiter
- QRM
  - sparking electrical contacts
  - radar/radiolocation – noise blanker (NB)
  - electrical lines often
  - Don’t go around banging on poles…

Receiver Limitations

- Any device that provides gain of a signal also provides gain of noise
- 1-3 μV for HF; 0.1 μV VHF
- SNR
  - signal to noise ratio
  - (Signal + Noise)/Noise in dB

Frequency Calibration

- analogue readout
- digital or numeric readout
- synthesized receiver –
- analogue – crystal oscillator
- need to periodically check with a crystal calibrator (100 kHz) – can also tune into CHU or WWV (not best approach)

How do Receivers Work?

- crystal radio (with diode)
- autodyne
  - simple but poor quality (poor stability, selectivity and sensitivity) – cheap QRP rigs
- superheterodyne
  - used in all good quality receivers
  - desired incoming sigs converted to common frequency and processing done at an intermediate frequency IF

How do Receivers Work?

- changing incoming freq to IF done by mixing a locally generated sig from a local oscillator
- non-linear element (diode) produces 4 outputs for two frequencies applied as input (FFT) – one then either sums or takes the difference to get the desired IF

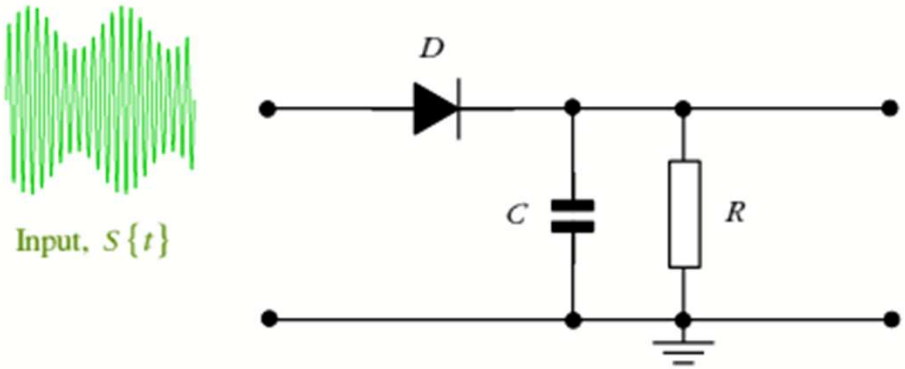


Figure 9.2 Envelope Detector (AM Demodulator/Detector).

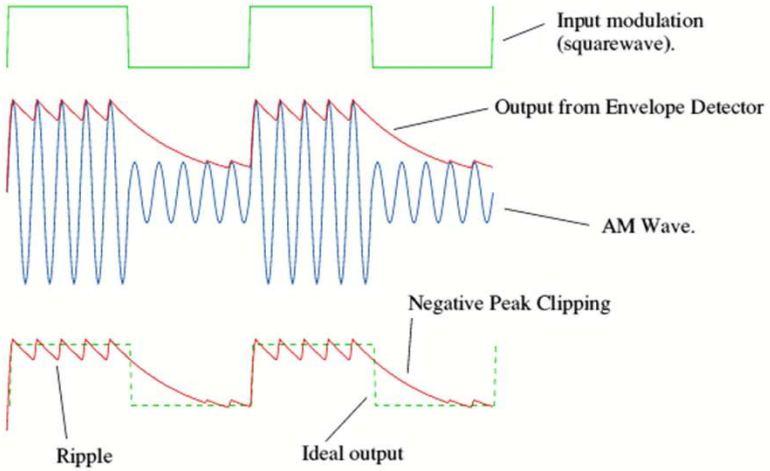


Figure 9.3 Ripple & Peak Clipping effects.

AM Receiver

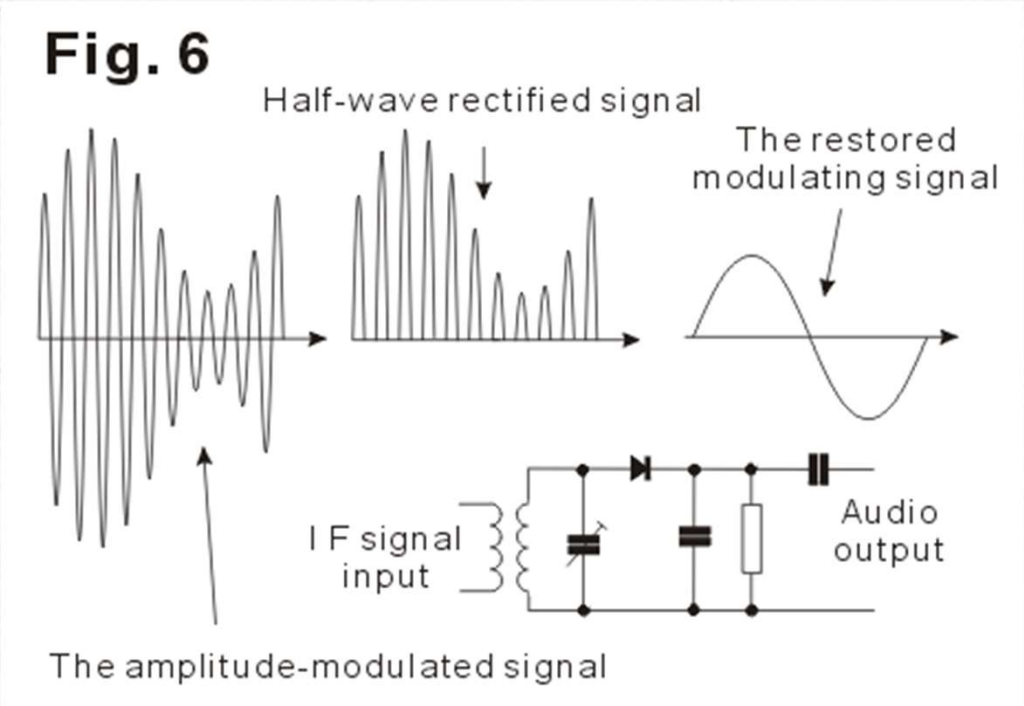


Fig. 6
Half-wave rectified signal
The restored modulating signal
I F signal input
Audio output
The amplitude-modulated signal

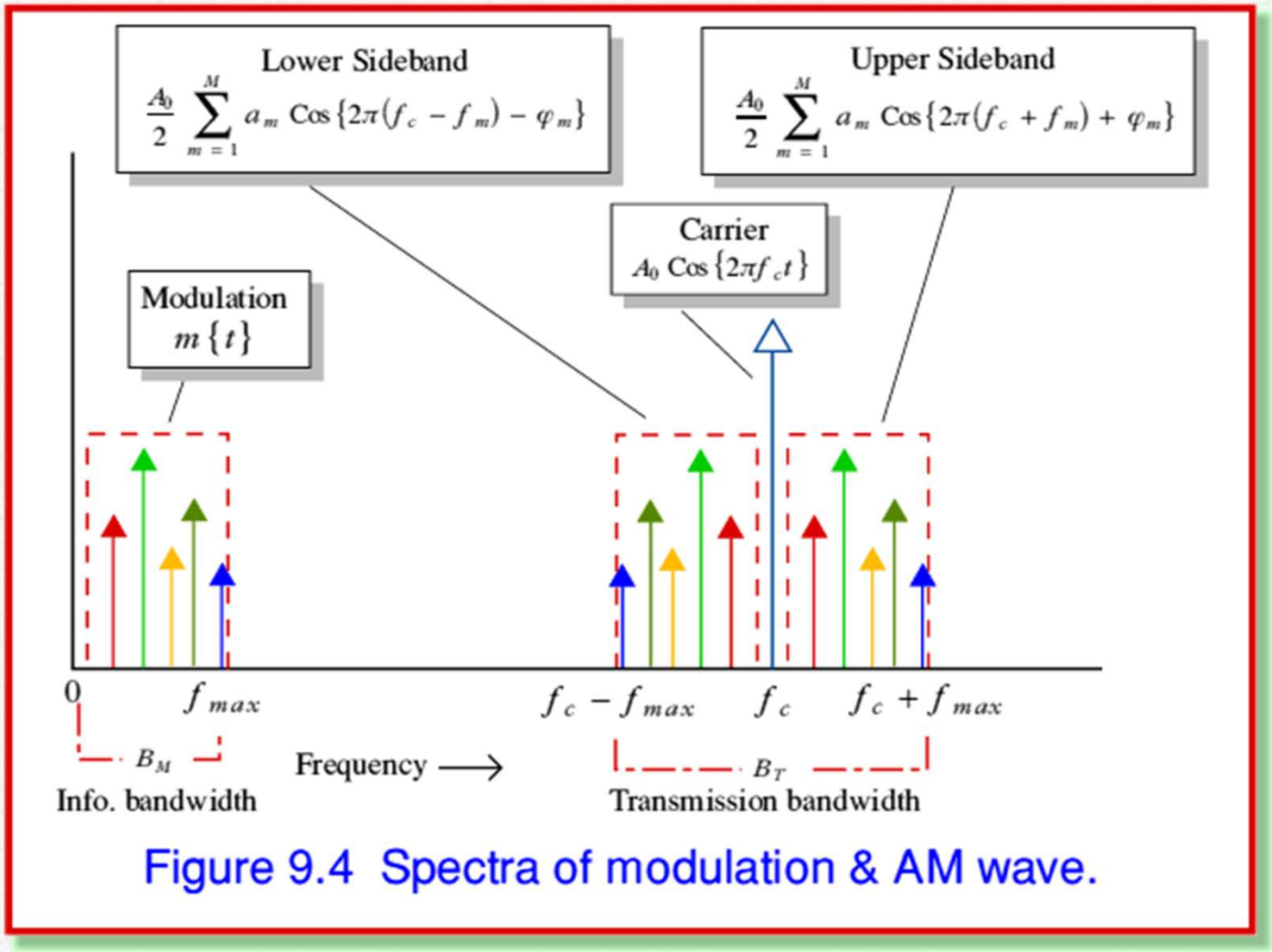
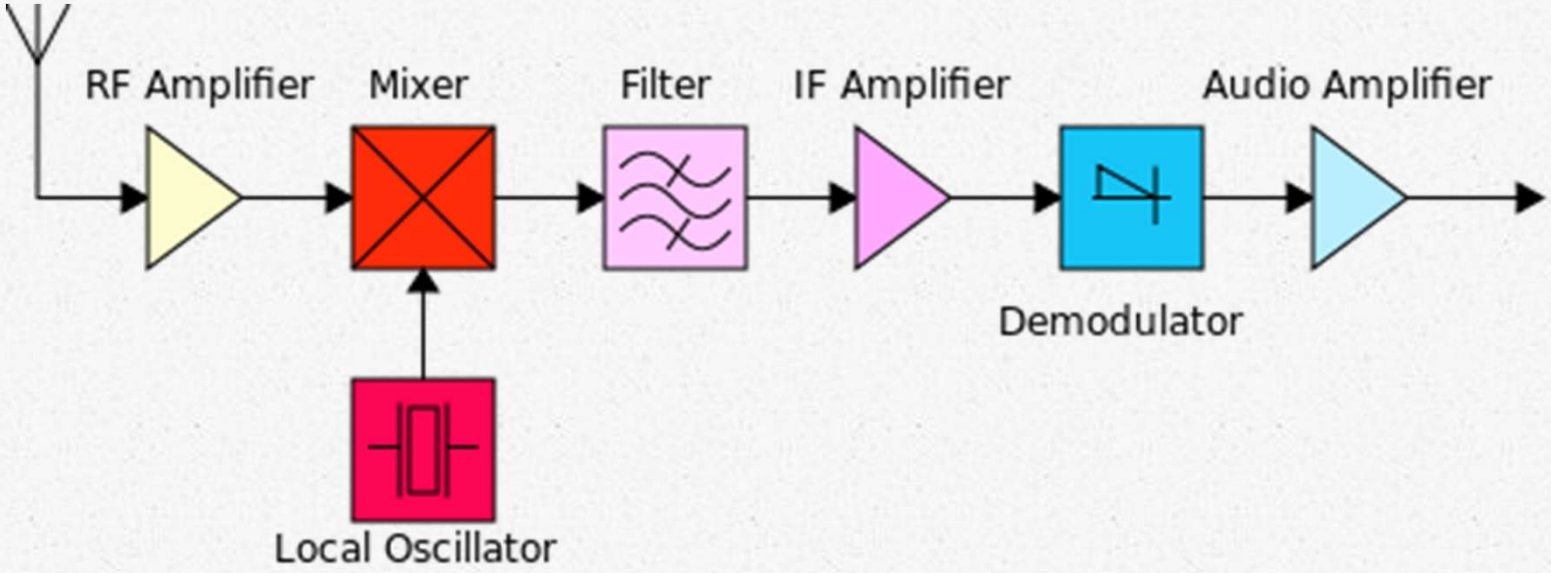
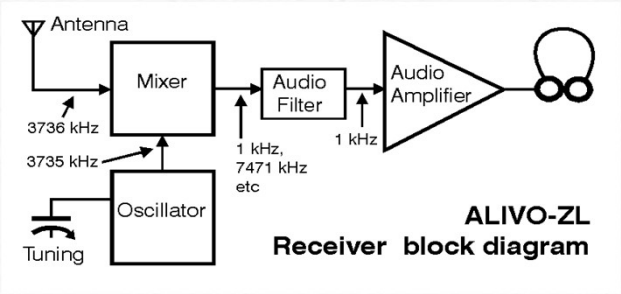


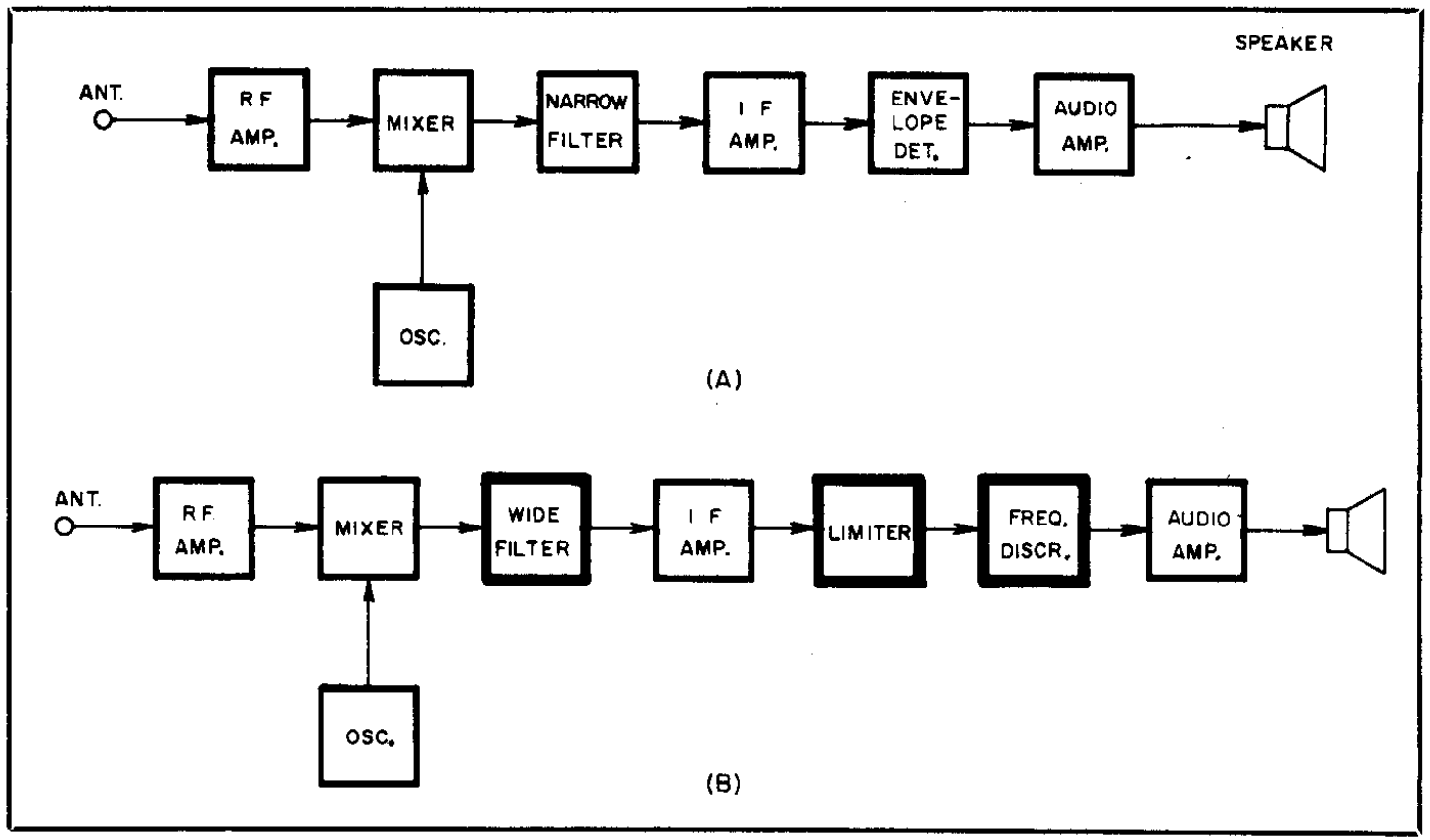
Figure 9.4 Spectra of modulation & AM wave.

Superheterodyne Receiver AM



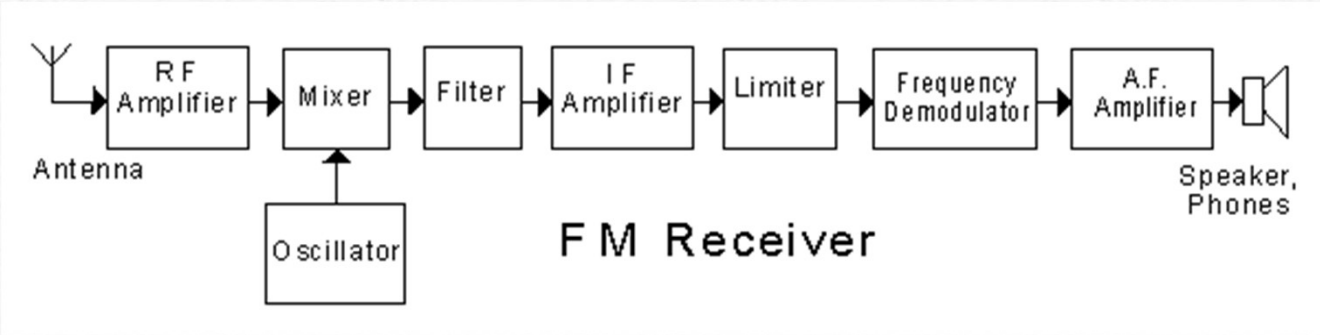


Receiving FM

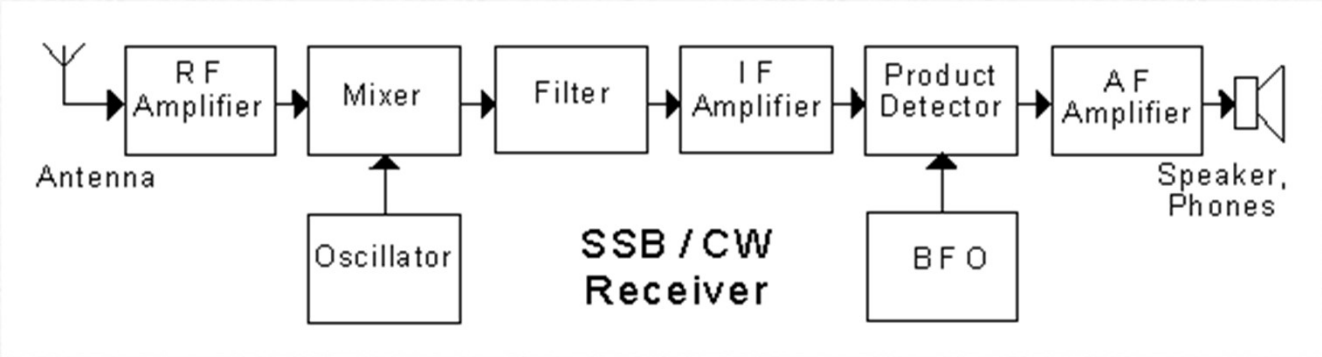


FM

- Limiter – removes all traces of AM
- Frequency Discriminator – coverts frequency variations into voltage variations
- Phase Locked Loop with ICs
- Quadrature or ratio detectors in analogue



Receiving SSB



S-Meter

reading	HF		Signal Generator emf
	µV (50Ω)	dBm	dB above 1uV
S9+10dB	160.0	-63	44
S9	50.2	-73	34
S8	25.1	-79	28
S7	12.6	-85	22
S6	6.3	-91	16
S5	3.2	-97	10
S4	1.6	-103	4
S3	0.8	-109	-2
S2	0.4	-115	-8
S1	0.2	-121	-14

SDR

- Not on Exam…

Conclusion

Questions