Modulation

1

The "Time Domain"

(the sine wave)

2

The "Frequency Domain"

← Increasing Frequency (ν)

| 10^{24} | 10^{22} | 10^{20} | 10^{18} | 10^{16} | 10^{14} | 10^{12} | 10^{10} | 10^{8} | 10^{6} | 10^{4} | 10^{2} | 10^{0} | ν (Hz) |

Ham Radio

γ rays | X rays | UV | IR | Microwave | FM | AM | Long radio waves

Radio waves

| 10^{-16} | 10^{-14} | 10^{-12} | 10^{-10} | 10^{-8} | 10^{-6} | 10^{-4} | 10^{-2} | 10^{0} | 10^{2} | 10^{4} | 10^{6} | 10^{8} | λ (m) |

Increasing Wavelength (λ) →

Visible spectrum

380 V 450 B 495 G 570 Y 590 O 620 R 750
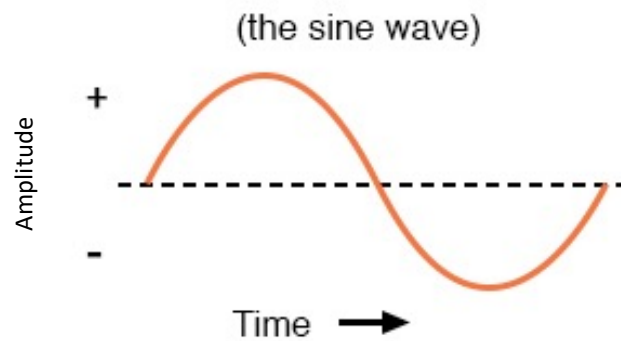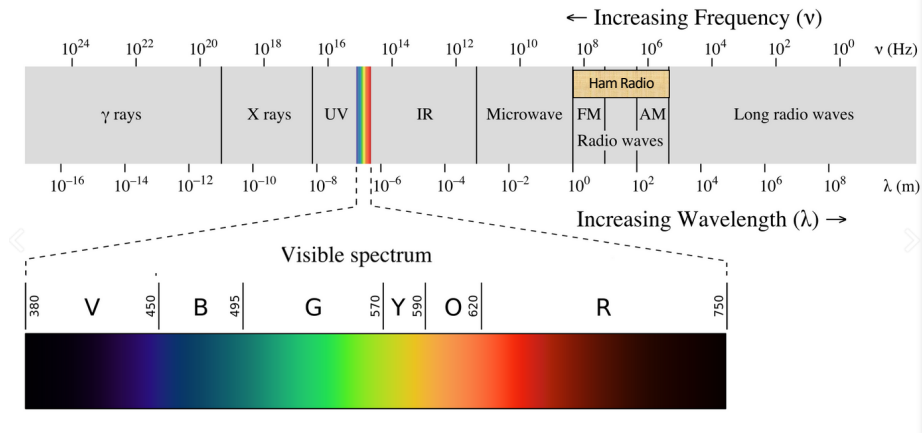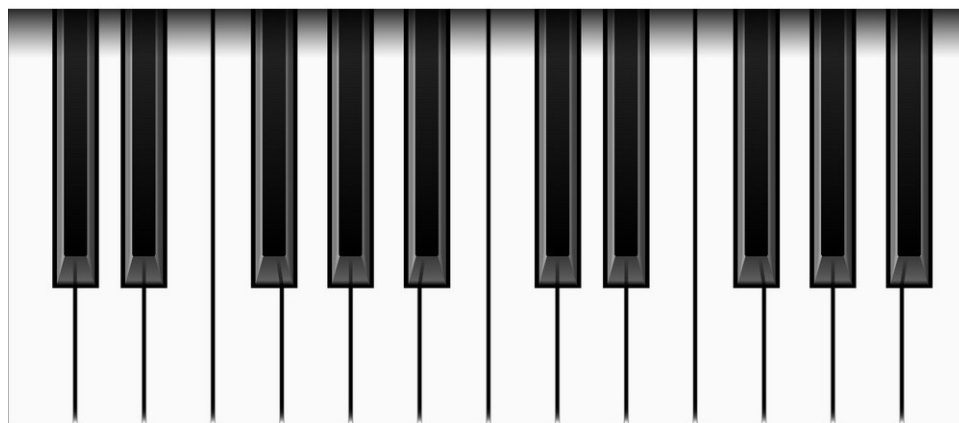
3

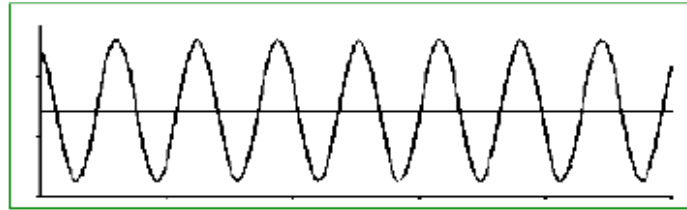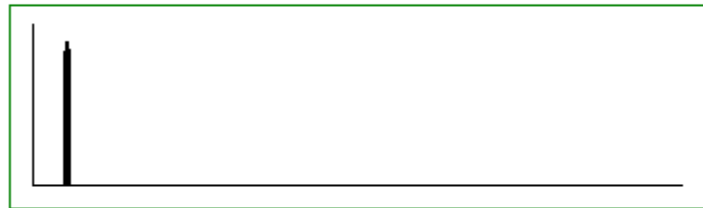# The Sound "Frequency Domain"

Frequency

4

Time vs. Frequency

Fixed
Frequency
Signal

Time
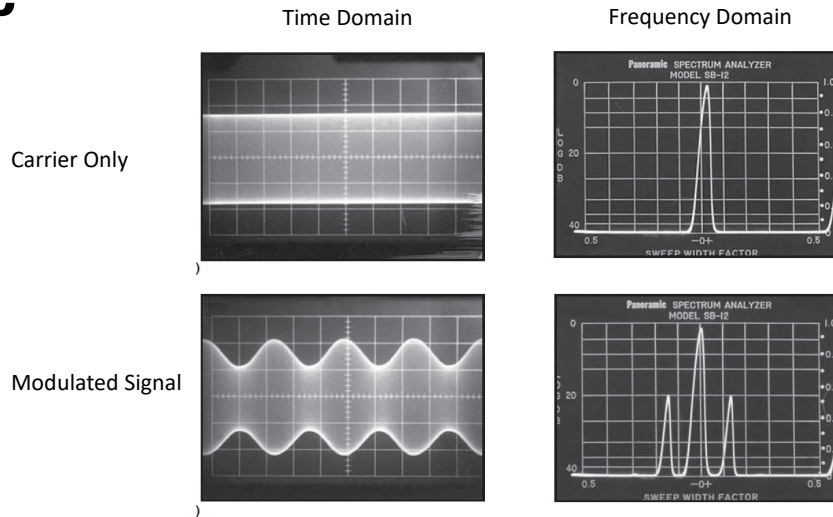
Frequency
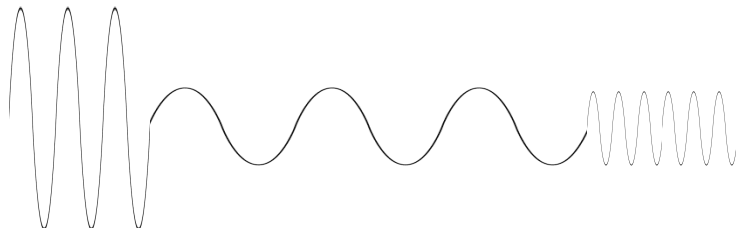Spectrum

Frequency

The Spectrum of a Sine Wave

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AM

6

Carrier Amplitude Modulated by a Pure Tone

Time Domain | Frequency Domain

Carrier Only

Modulated Signal

7

The Two Features of Audio

- Frequency
- Amplitude

8

AM Voice Modulation

- The deviation = voice frequency
- Voice amplitude changes power output
- Filter limits audio frequency to 3kh
- Max Deviation is 3khz
- There are two sidebands
- The total bandwidth is 6khz
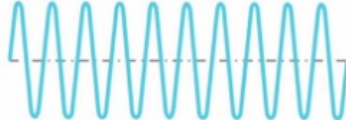
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Amplitude Modulation

Amplitude Modulation (AM)

Input (Modulating Wave)

The information you want to transmit - such as your voice

Carrier

The radio frequency you want to use

Modulated Result

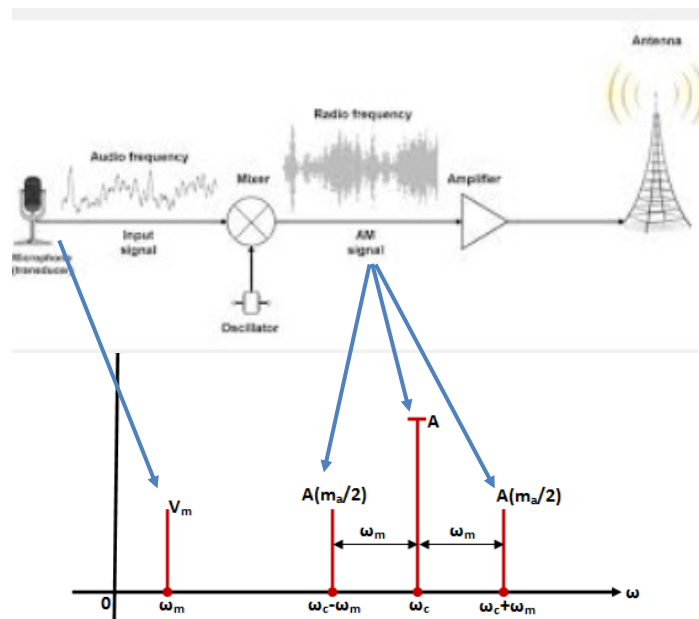The signal that comes out of the radio
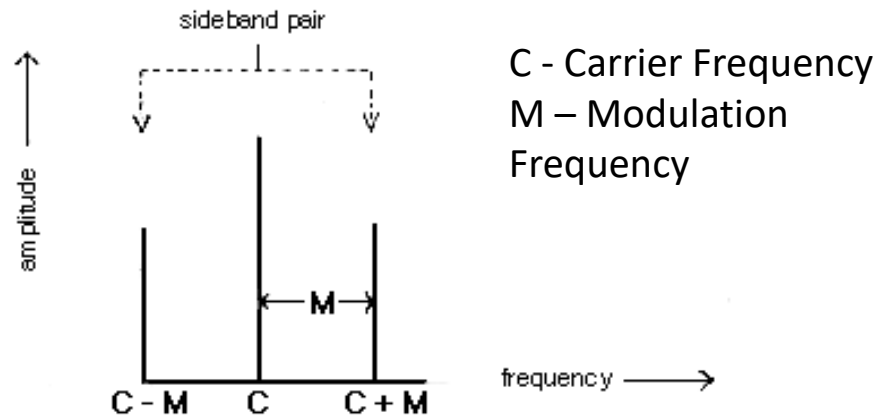
10

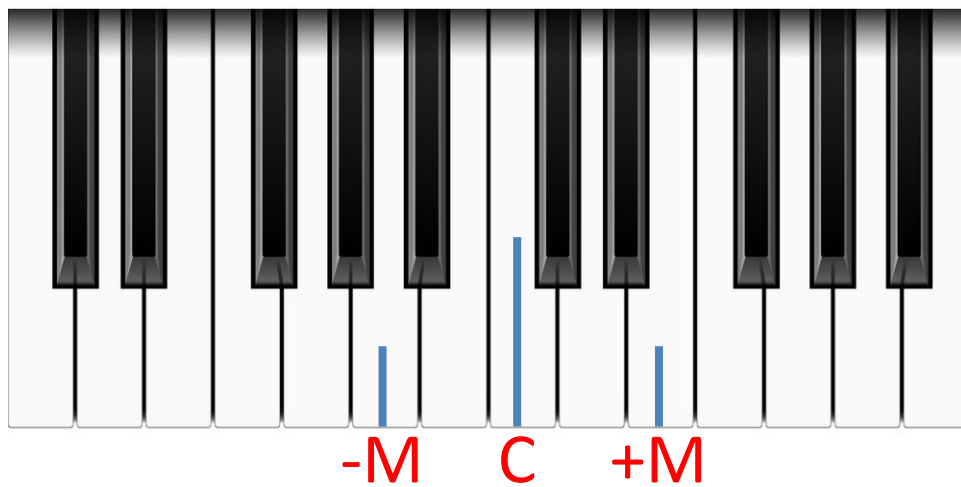# Transmitting and Receiving an AM Signal

AM Transmitter

Modulation Creates Two Products

C - Carrier Frequency
M – Modulation Frequency

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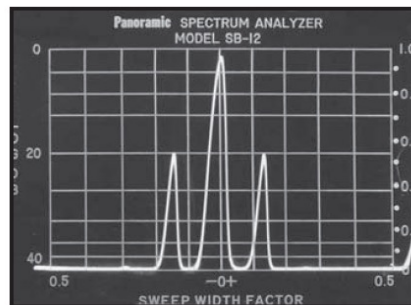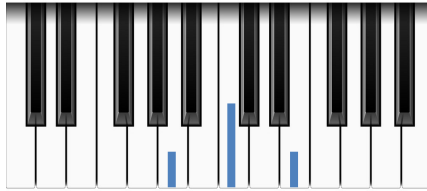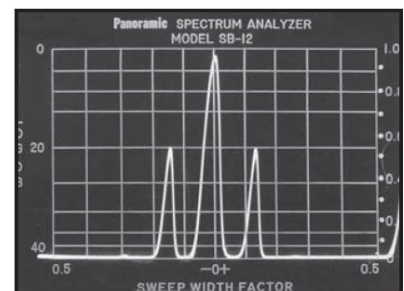# It's Sorta Like a Chord

-M   C   +M

14

AM Has Two "Sidebands"
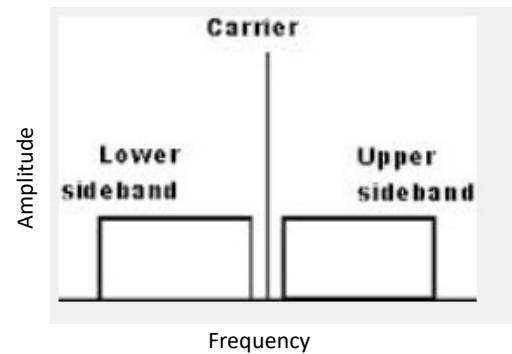
15

Can We Make AM Better?

- Most of the power is in the carrier
- The upper and lower sidebands are the same!
- Let's remove the carrier and one sideband
- We call that SINGLE SIDEBAND

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SSB

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SSB Voice Modulation

- Starts with an AM signal
- Filter out one sideband
- Bandwidth is half the AM bandwidth

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Single Side Band Signals

Carrier and Upper sideband Filtered out
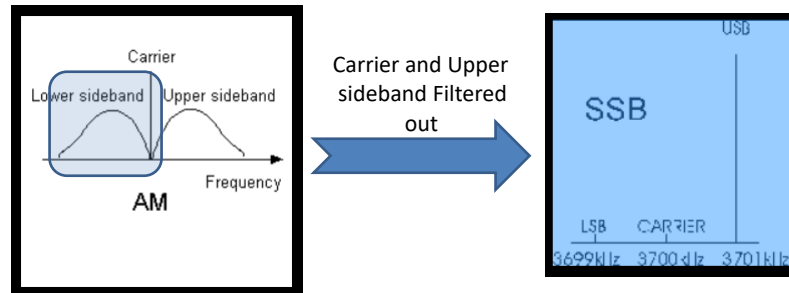
19

Single Sideband Modulation

- SSB is amplitude modulation with the carrier and one of the side lobes removed

- No carrier power is transmitted

- Only one copy of the modulation is transmitted
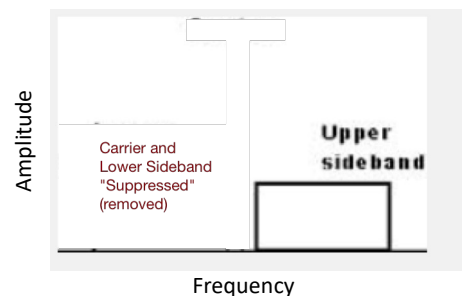
20

What If We Disagree on Carrier Frequency?

Modulated Result

Input (Modulating Wave)

Modulator

Demodulator

Input (Modulating Wave)

Carrier

Carrier
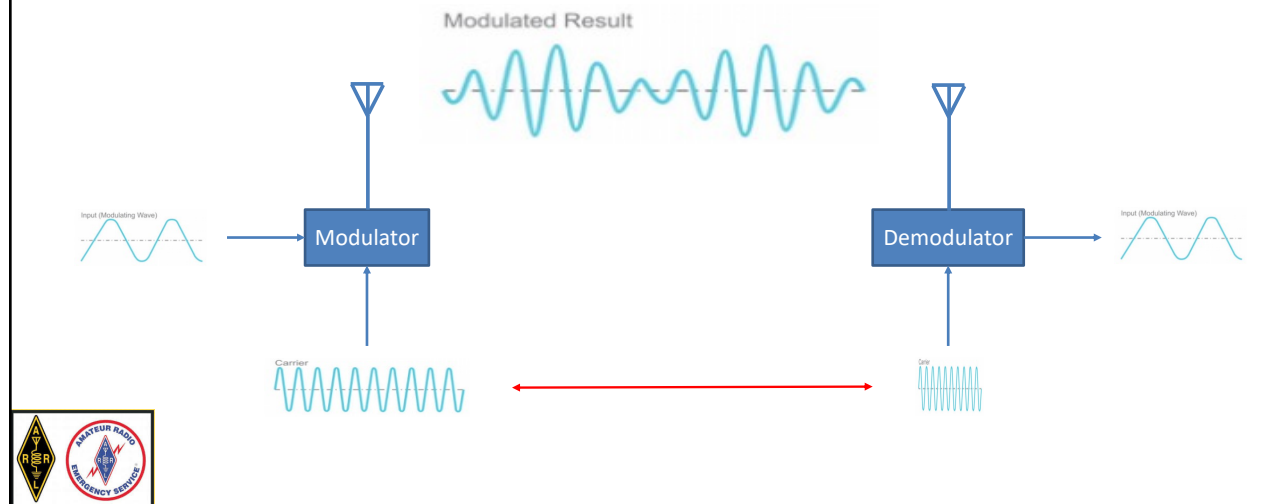
21

As You Move "C" the Pitch of "M" Changes

C   +M
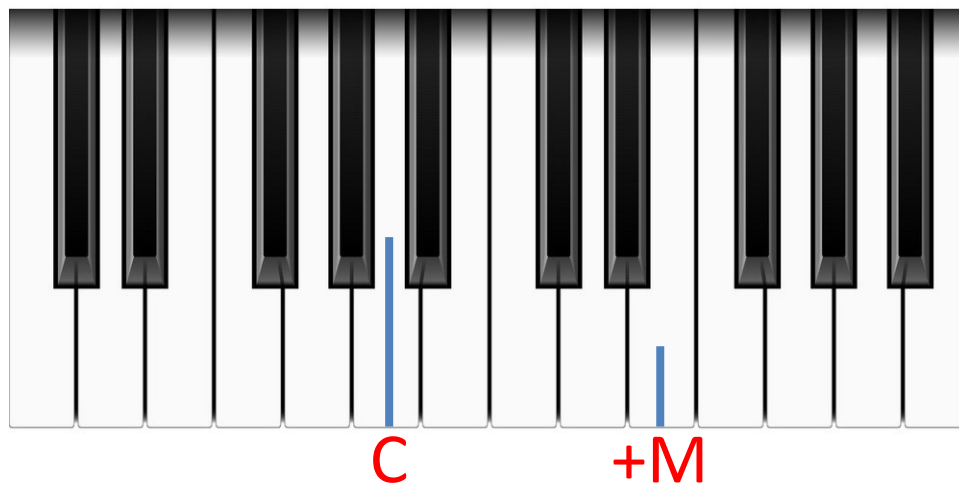
22

Being Upside Down Sounds Really Weird!

+M   C
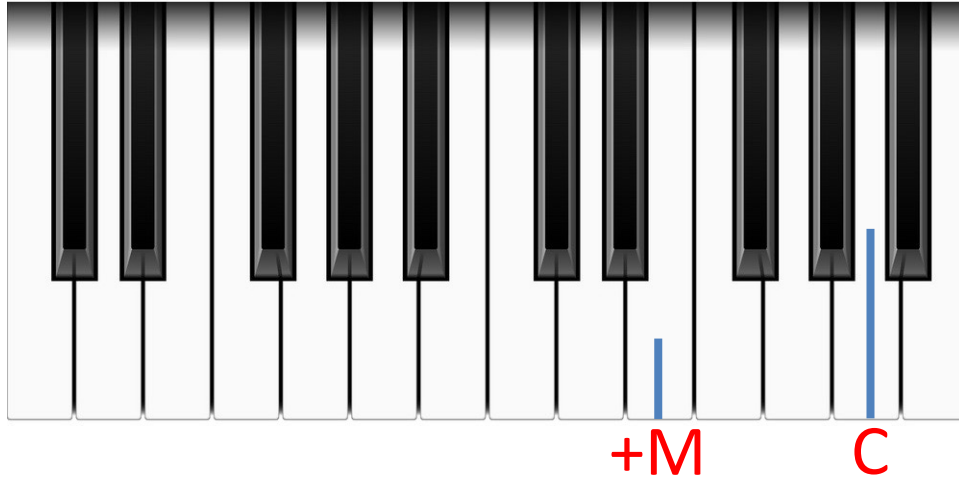
23

SSB is Always Tuned by Ear

- But you do need to get the choice of sideband correct
- We do upper on higher bands (20m and above)
- We do lower on lower bands (40m, 80m, 160m)

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FM

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FM Modulation is More Complicated

- We still need to transmit
  both frequency and amplitude

- But FM output power *does not* change

- We encode *both* amplitude and
  frequency with just frequency!

- Let's start with a simpler case

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AM vs. FM

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Frequency Modulation

The information you want to transmit - such as your voice

The radio frequency you want to use

The signal that comes out of the radio
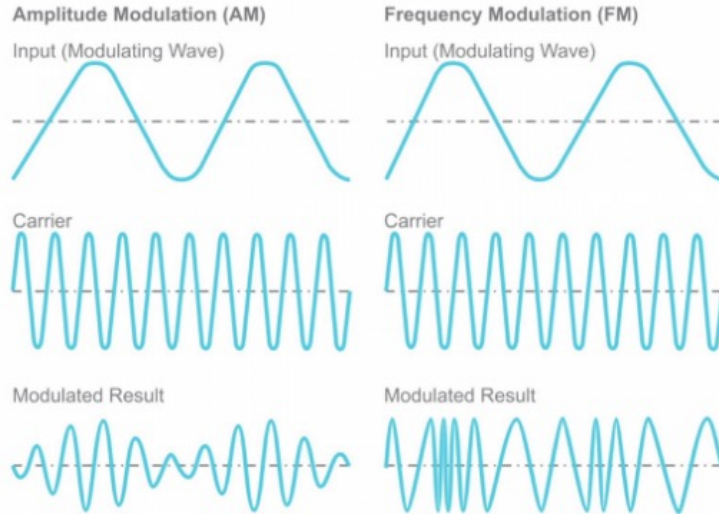
28

FSK Modulation

- Only 2 amplitudes in the data
- Output jumps between two frequencies
- Max deviation is twice the higher deviation [1 in this case]

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FM Audio Modulation

- Both amplitude and frequency change the deviation
- By how much?
- "Peak Deviation"
- The amount that amplitude changes frequency
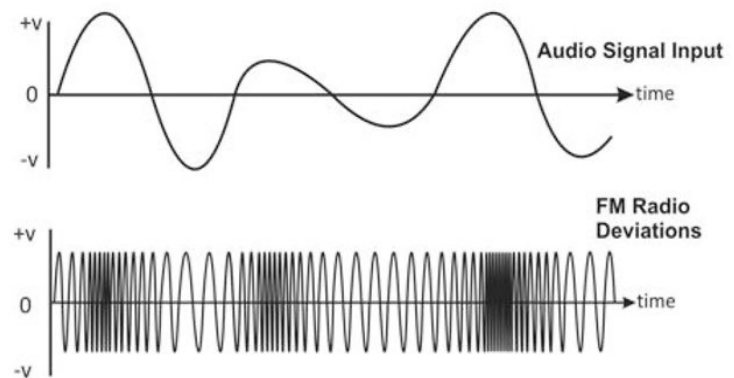
30

Why Use Different Types of Modulation

- AM?
  - Just say no! It's too inefficient
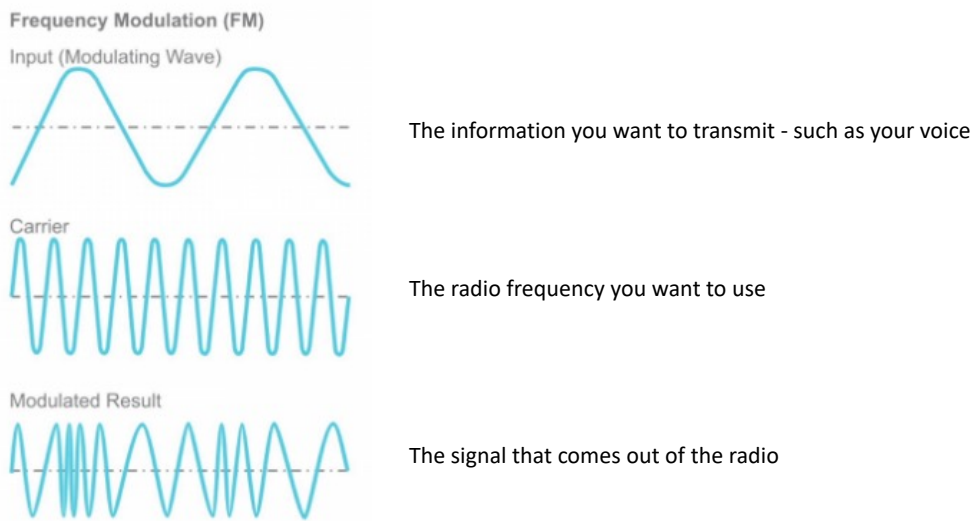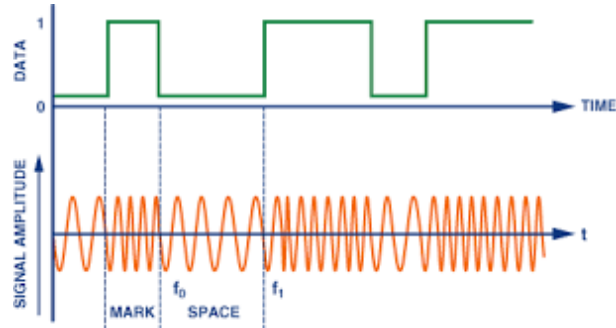- SSB?
  - Most efficient transmission of voice
- CW?
  - Just showing off?
  - Very efficient
  - Great for noisy conditions and weak signals
- FT8/JS8Call/etc/etc
  - Even more efficient than CW and can work when nothing else will
- FM?
  - Nearly cell phone quality
  - VHF and above

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The Secret is in the Bandwidth

- CW: 150 Hz
- SSB: 3 KHz
- FM: 10-15 KHz
- Fast Scan TV: 6 MHz

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Modulation Demo

- https://www.youtube.com/watch?v=W7Z
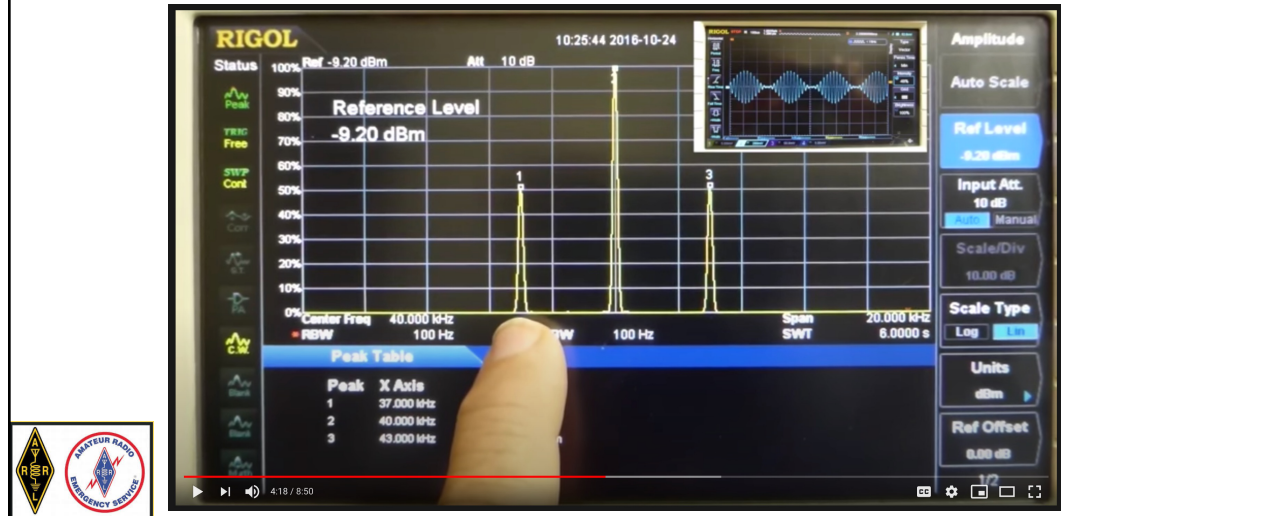
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More Fun With Modulation

- https://www.youtube.com/watch?v=Ru2UOSwRzt4
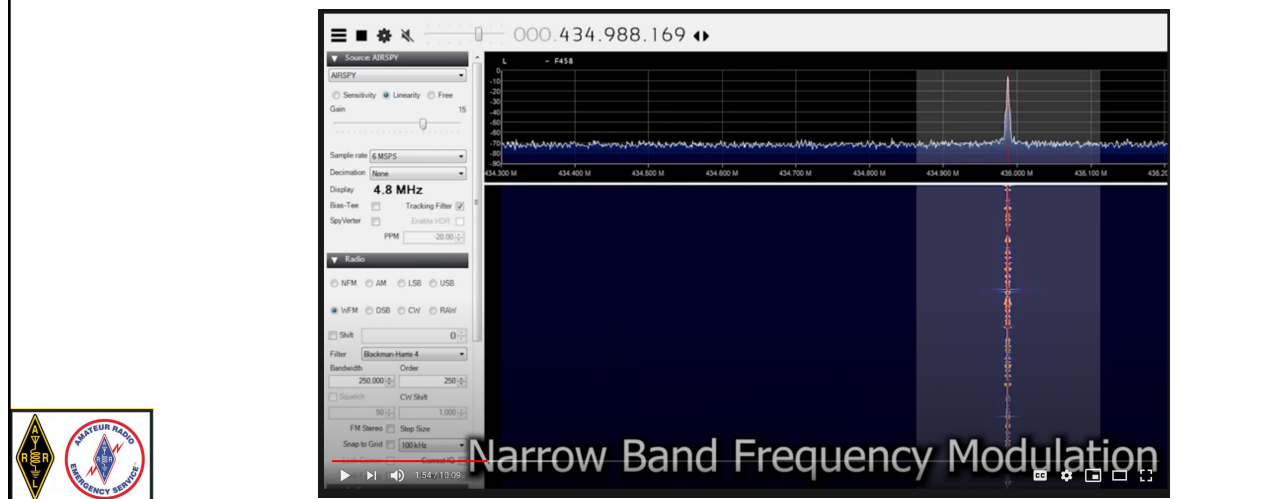
34

The Frequency Domain
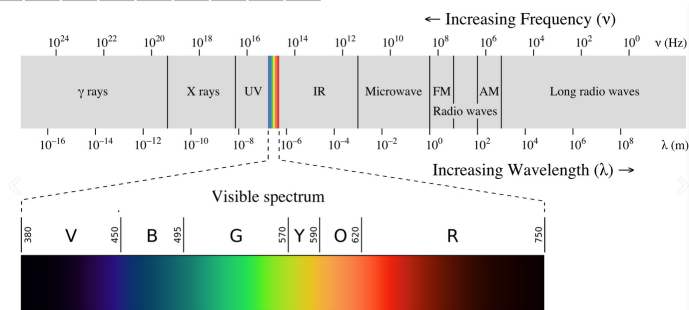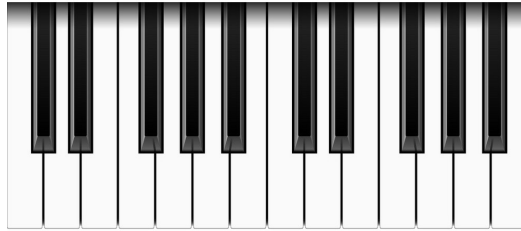
35

Deviation

- How Much Something Was Changed
- In our case, a frequency
- Carrier is *deviated* by modulation
- More deviation uses more bandwidth
- Kind of Modulation Changes the Math

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Time & Frequency Shown Together
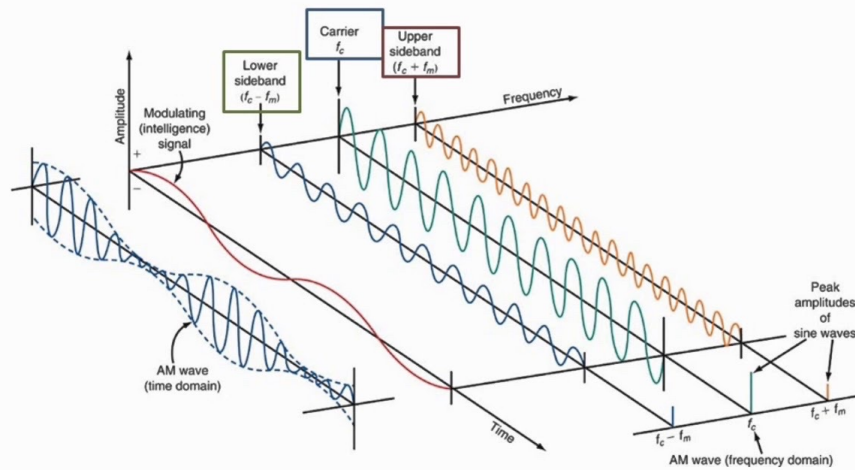
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The Three Changeable Things

- Amplitude
- Frequency
- Phase

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"Codes and Modes"

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Modes of Communication

- On/Off (CW)
- Analog Voice
- Analog Image
- Digital Voice
- Text and Data

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Morse Code

- Continuous wave (CW)
- Modulated continuous wave (MCW)
- Frequency shifting continuous wave

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Analog Voice

- Amplitude modulation (AM)
- Double-sideband suppressed carrier (DSB-SC)
- Independent sideband (ISB)
- Single sideband (SSB)
- Compatible sideband transmission (AME)
- Frequency modulation (FM)
- Phase modulation (PM)

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Digital Voice

- APCO P25
- D-STAR (AMBE over GMSK)
- DMR (FSK modulation variant with TDMA)
- System Fusion (AMBE CODEC with C4FM)
- FreeDV (PSK)
- M17 (Codec2 with 4FSK)

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Image

- Amateur television (ATV)
- Slow-scan television (SSTV)
- Facsimile

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Text and Data

- Amateur teleprinting over radio (AMTOR)
- D-STAR (128 kbit/s), data-only mode)
- Hellschreiber, a facsimile-based teleprinter
- Discrete multi-tone modulation (MT63 and others)
- Multiple frequency-shift keying (MFSK)
  - FSK441, JT6M, JT65, and FT8
  - Olivia MFSK
  - JS8

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More Text and Data

- Packet Radio (AX25)
  - AMPRNet
  - APRS
- PACTOR (AMTOR + packet radio)
- Radioteletype (RTTY) (FSK)
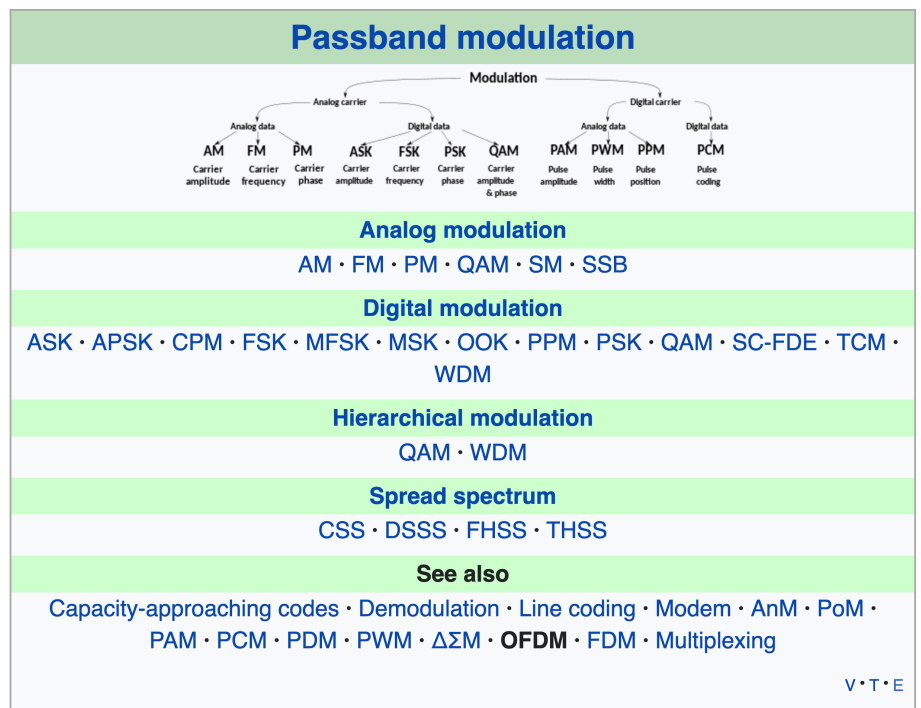- Multimedia over 802.11
- Spreadspectrum

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One More Time

- Phase-shift keying:
  - PSK31: 31 baud binary PSK
  - QPSK31: 31 baud quadrature PSK
  - PSK63: 63 baud binary PSK
  - QPSK63: 63 baud quadrature PSK

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A Family Tree

Passband modulation

Modulation

Analog carrier — Digital carrier

Analog data — Digital data — Analog data — Digital data

AM · FM · PM · ASK · FSK · PSK · QAM · PAM · PWM · PPM · PCM

Carrier amplitude · Carrier frequency · Carrier phase · Carrier amplitude · Carrier frequency · Carrier phase · Carrier amplitude & phase · Pulse amplitude · Pulse width · Pulse position · Pulse coding

Analog modulation
AM · FM · PM · QAM · SM · SSB

Digital modulation
ASK · APSK · CPM · FSK · MFSK · MSK · OOK · PPM · PSK · QAM · SC-FDE · TCM · WDM

Hierarchical modulation
QAM · WDM

Spread spectrum
CSS · DSSS · FHSS · THSS

See also
Capacity-approaching codes · Demodulation · Line coding · Modem · AnM · PoM · PAM · PCM · PDM · PWM · ΔΣM · **OFDM** · FDM · Multiplexing

V · T · E

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