



## Chapter 5 Radio Signals

Modulation Modes

Digital Modes

RTTY, PSK, Packet



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# Modulation


Combining information wave with the radio wave at the transmitter.

- Morse or CW is on-off keying
- AM varies the field *amplitude*
- FM varies the field *frequency*
- PM varies the field *phase*
- Modulations by type of information
  - Voice or *phone*
  - Data; *Analog* or *Digital*



# Demodulation

Recovering the information wave from the radio wave at the receiver

- CW – Makes a *beat* note or *heterodyne* from *mixing* with a reference oscillator 
- AM – Sideband frequencies mix with carrier
- SSB – Sideband frequencies mix with a carrier oscillator
- FM – Signal frequency is compared to a reference frequency in a frequency discriminator



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# Amplitude Modulation

Varies the power of the RF signal in proportion to the information signal analog voltage

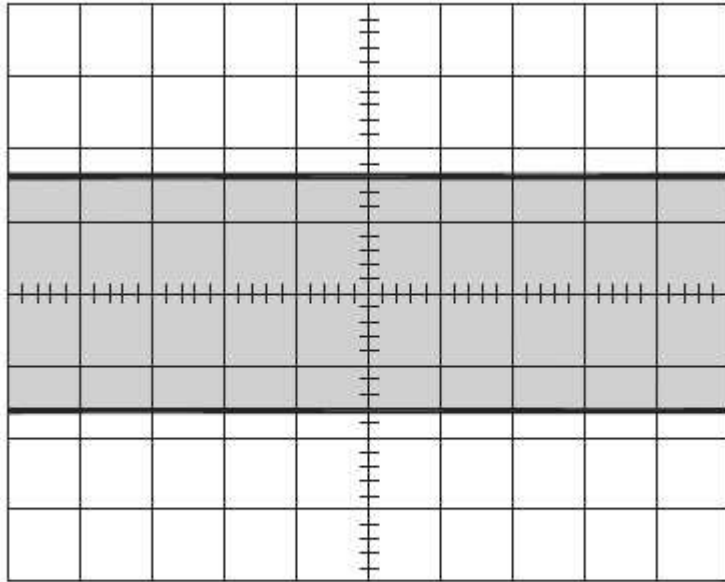
- Signal envelope varies at the information rate
- *Sidebands* are created – *USB, LSB*
- Same information is in each sideband so one may be suppressed – *SSB*
- The base frequency or *carrier* contains no information so it may be suppressed – *SSBSC*
- *SSB bandwidth* equals the highest information frequency.



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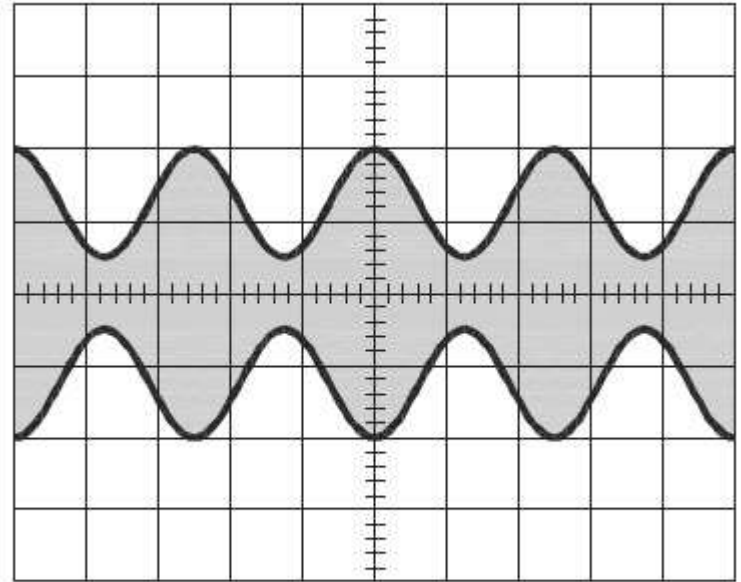


# AM Waveforms



(A)

GLM0052



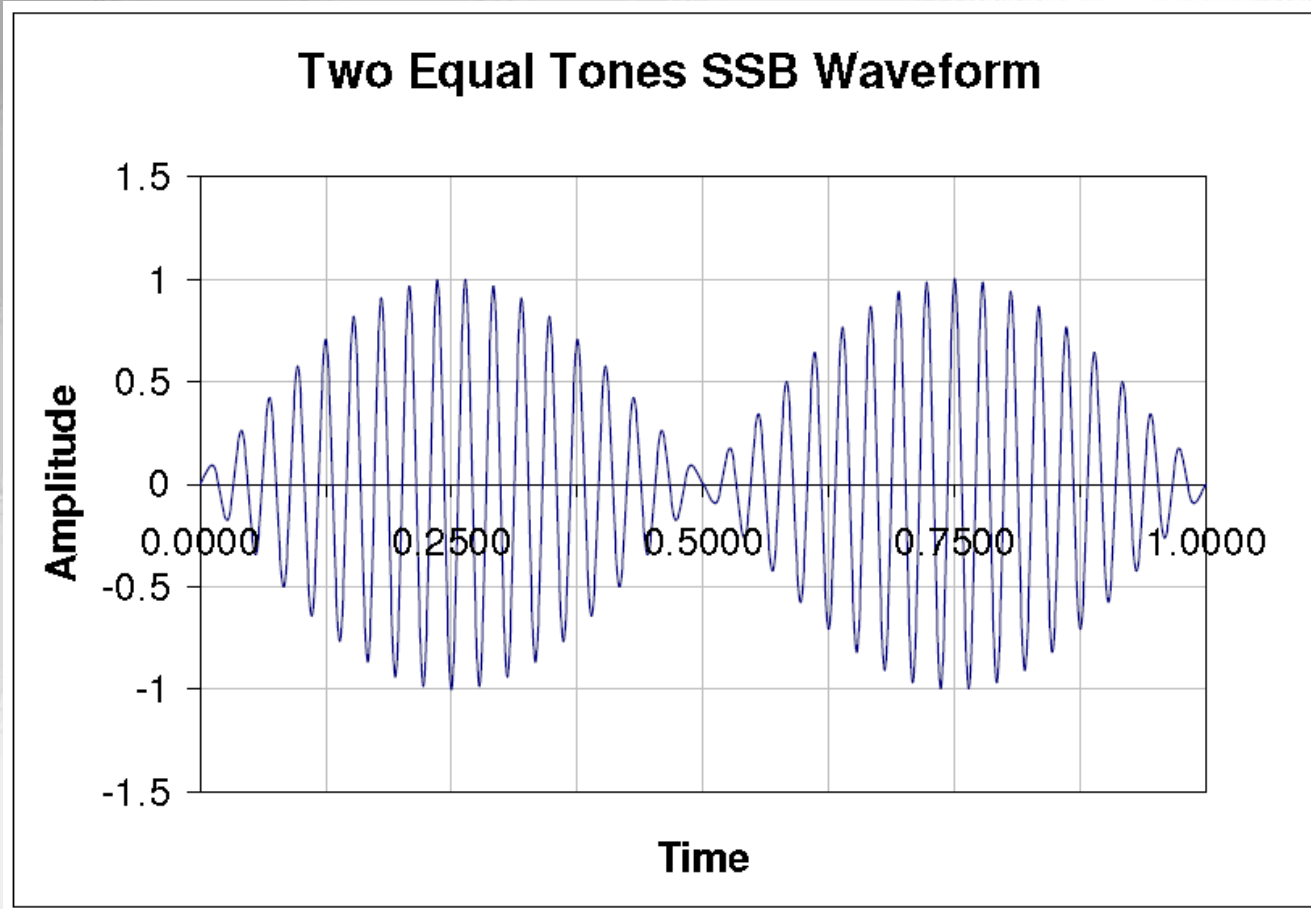
(B)



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# SSB Waveforms



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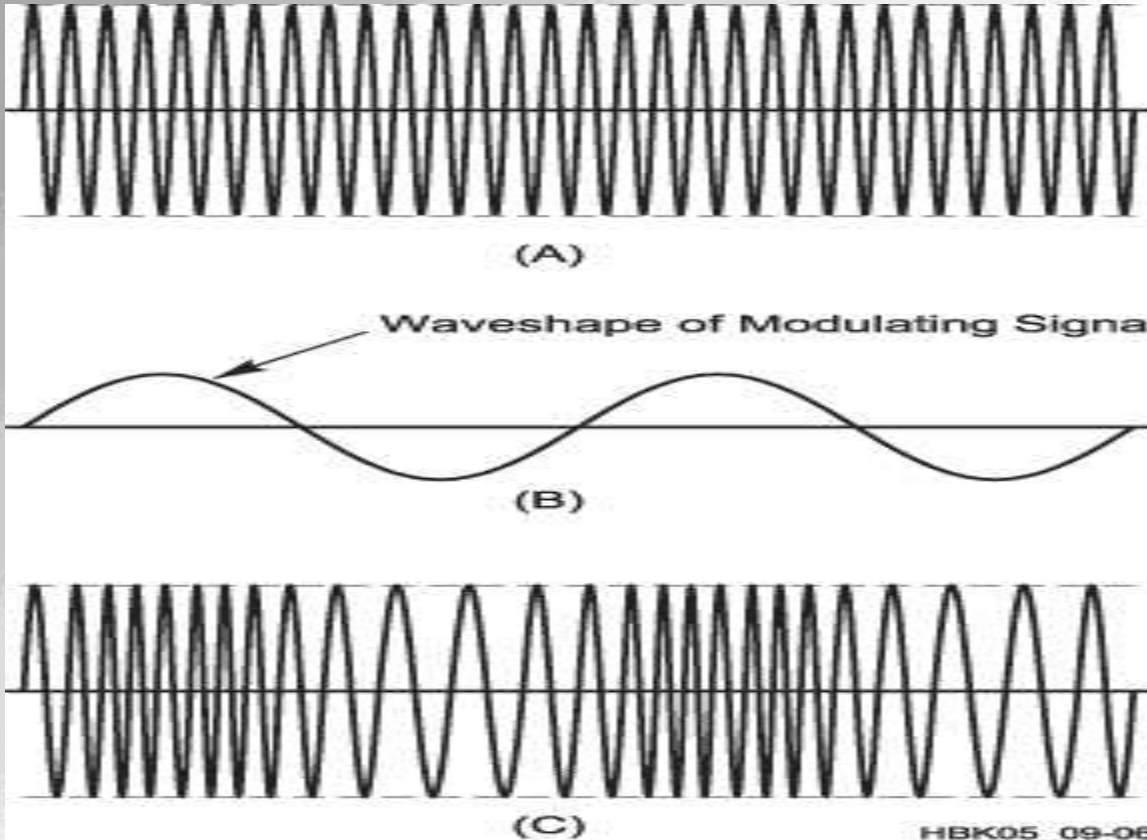
# Frequency Modulation

Varies the frequency (or phase) of the radio wave in proportion to the analog information

- The amount of frequency change is called *deviation*
- Phase and Frequency modulation are similar except for information frequency emphasis
- FM envelope is constant level
- Pairs of sideband frequencies are created
- Bandwidth usually wider than highest information frequency



# FM Waveforms



Unmodulated  
Carrier

Modulating  
Signal

Modulated  
Carrier



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# Typical Bandwidths

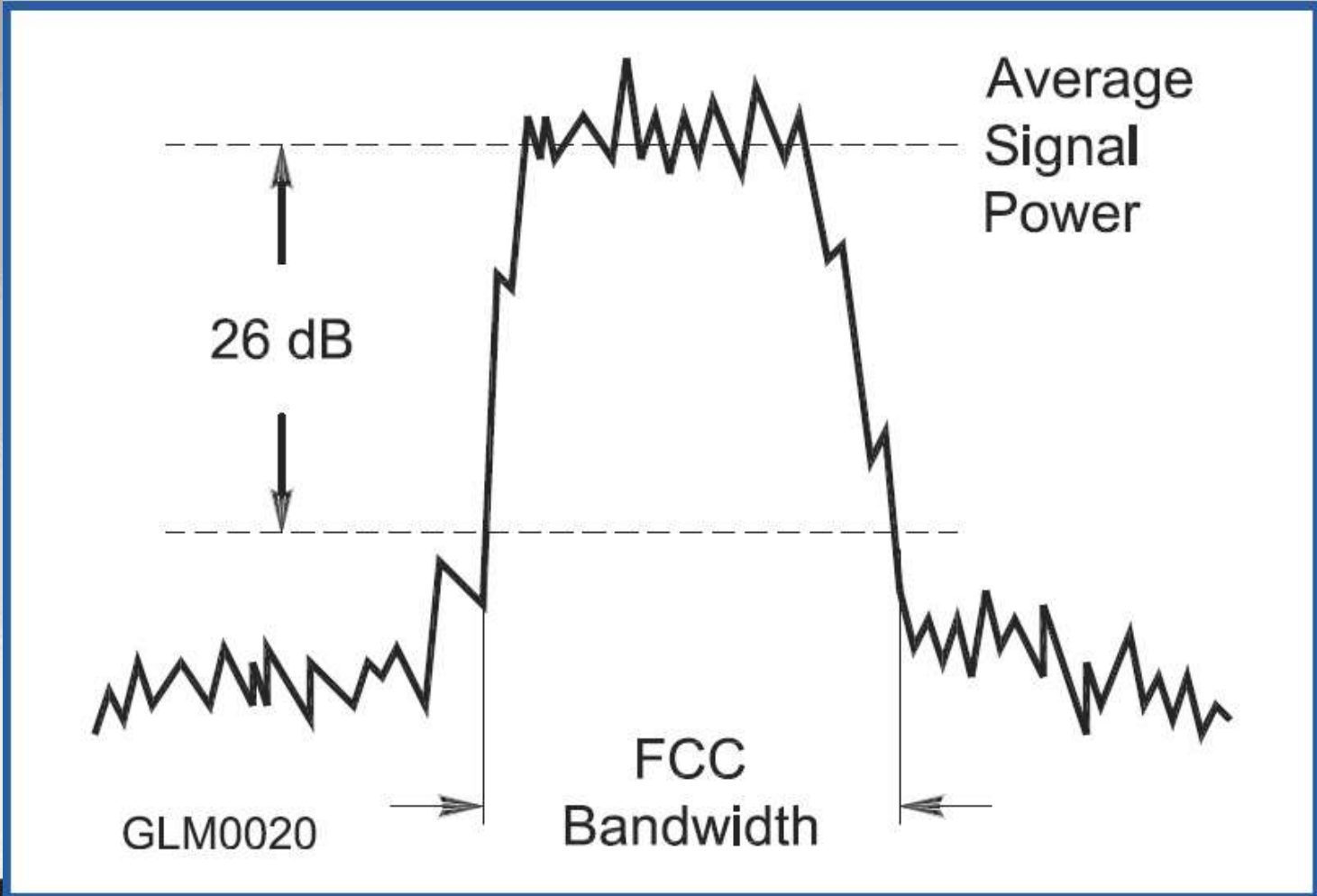
**Table 5-1**

## **Amateur Signal Bandwidths**

<i>Type of Signal</i>	<i>Typical Bandwidth</i>
AM voice	6 kHz
Amateur television	6 MHz
SSB voice	2 to 3 kHz
Digital using SSB	500 to 3000 Hz (0.5 to 3 kHz)
CW	100 to 300 Hz (0.1 to 0.3 kHz)
FM voice	5 to 15 kHz



# FCC Bandwidth Definition



# Digital Modes

Digital information consists of binary values – 0 and 1. Sending binary values at high rates makes a wide bandwidth

- Each bit or group of bits is usually encoded into an analog feature of a tone – frequency, phase, etc. i.e.
  - low frequency  $\Leftrightarrow$  “1” , high frequency  $\Leftrightarrow$  “0”.
  - Phases 0, 90, 180, 270  $\Leftrightarrow$  “00”, “01”, “10”, “11”
- Tone may be transmitted by AM, FM, or SSB



# Digital Mode Terminology

Baud – the rate that symbols are sent

- Symbol – A tone containing one or more bits
- Bit rate can be higher than symbol rate
- Bandwidth increases with symbol rate
- Protocol – rules for encoding and decoding
- Duty cycle – the percentage of time at full power
  - RTTY – 100%, Reduce transmitter power to 50%
  - PSK – nearly 100%, Reduce power
  - TOR – Low, Can usually run full power



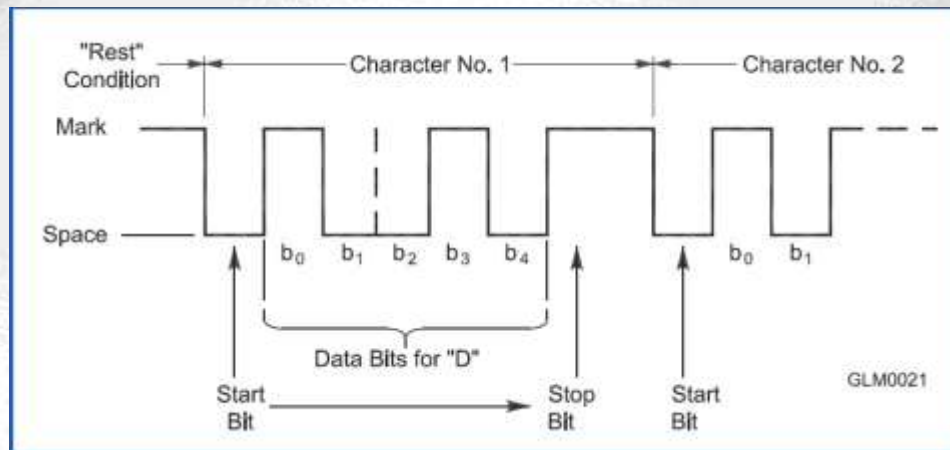
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# TTY and Baudot Code

TTY characters are Baudot encoded using five data bits framed by a start and stop.

- Start is a “0” or low
- Stop is a “1” or high, usually longer than other bits
- Five data bits can represent 32 characters



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# RTTY

The bits of baudot characters shift the frequency of a tone.



- The two frequencies are called mark (1) and space (0)
- Rate of shift determines character speed (WPM)
  - 45, 56, 75 Baud  $\Leftrightarrow$  60, 75, 100 WPM
  - Most Hams on HF use 45 Baud with 170Hz shift
  - Mark is 2125Hz, Space is 2295Hz
- FSK tone can be sent on Voice modes
  - On SSB, use Lower Sideband



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# Multi-Tone FSK


MFSK16 uses 16 tones in a 300Hz bandwidth

- Can be received through a 500Hz bandwidth CW filter
- Tones are 15.625 Hz apart
- Keying of tones is shaped to control bandwidth and reduce effects of ionospheric *selective fading*
- Good performance with weak sky-wave signals
- Data rate is about 42WPM



# Phase Shift Keying and PSK31



In PSK, the phase of the tone may change for each symbol. The phase reference is transmitted at the beginning of a message and/or between symbols.

- Sounds like a buzzing tone 
- PSK31 is popular for sending from a keyboard
  - Symbol rate is 31.25Baud
  - Varicode – shorter codes for most common characters
  - Up to 50 WPM under good conditions
  - Signals can be copied through noise
  - Encoded and decoded by computer sound cards



# Packet over Radio

Packet is a collection of data characters sent in one message.

- Packet Radio for VHF/UHF FM uses 1200Baud or 9600Baud
- Packet not suited for HF because of fading
- Error Detection and Correction
  - CRC checksum 
  - ACK or NAK
  - ARQ and FEC 

# Packet Contents



Header - Contains routing, control, status and error correction data

Data (payload) - Contains data being transferred

Trailer - Contains status and error detection data

GLM0022




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# TOR – Teletype Over Radio

PACTOR and WINMOR improve teletype reliability in presence of fading and noise.

- Short bursts of characters with error detection and correction 
- FSK (PACTOR I), PSK (PACTOR II, III)
- Error detection and Automatic Repeat Request
- WINMOR is popular for WinLink 2000 HF email system for sailboats and campers.