Chapter 8
Radio Modes and Equipment

Chapter 8
Radio Modes and Equipment

- Digital Communications
- Spread Spectrum
- Fast and Slow scan television
- Receiver sensitivity and noise
- Dynamic range
- Phase noise
- Capture Effect

Digital Communications
Symbol Rate, Data Rate, and Bandwidth

- Digital data speeds
  - Air link
    - Speed of data transmitted over the air
  - Data stream
    - Speed of data within the computer equipment
  - Data throughput
    - Overall data speed of the entire communication system

Digital Communications

Symbol Rate, Data Rate, and Bandwidth

- Digital signal rate measured in Baud
  - The number of data symbols transmitted per second.
  - A rate of one baud means that one symbol is transmitted per second.

Digital Communications

Symbol Rate, Data Rate, and Bandwidth

- A stream of digital data displayed on an oscilloscope looks like a series of pulses with varying patterns.

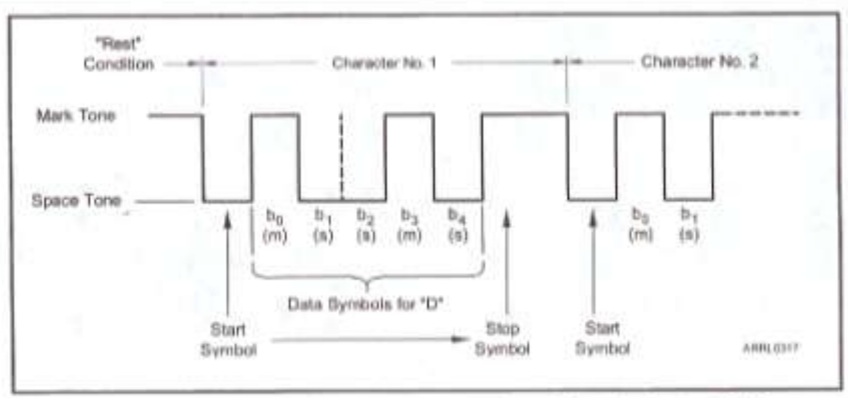

Figure 8-1 — The pattern of symbols transmitted for the letter "D" in Baudot code. Each "bit" of the code is transmitted as one symbol.

Digital Communications

Symbol Rate, Data Rate, and Bandwidth

- Digital signal “speed”…The rate of information transfer measured in units of data per second.
  - Transmitted signal Symbol Rate (Baud)
  - Data Rate
    - May be higher than symbol rate with some protocols.
    - Example. 9600 bps packet – 4800 baud

Digital Communications

Symbol Rate, Data Rate, and Bandwidth

- Digital Signal Bandwidth
  - The higher the signal's baud, the wider the transmitted signal will be.

$$BW = B \times K$$

BW- Bandwidth

B- Baud

K - Factor relating to the shape of the keying envelope.

Digital Communications
Protocols And Codes

- Codes
  - Method by which information is converted to and from digital data. A set of rules for changing information from one form to another. Doesn't specify how data is transmitted (modulation type).
  - Elements
    - Symbols that make up the code
      - Numbers, bits, tones, etc.

Digital Communications
Protocols And Codes

- Most codes use a fixed number of bits for each character.
- Some codes have a variable length of bits and/or vary the number of bits in each character or symbol - Varicode
  - Morse elements and characters are of different lengths (dit, dah, space, etc.)
  - PSK31 elements are the same length but its characters have different lengths.

Digital Communications
Protocols And Codes

- Baudot - Used by RTTY
  - Two elements – Mark & Space (same length)
    - Each element one data bit
    - Combinations in groups of five bits form characters
    - 32 characters possible (2^5)
    - Upper case only
    - Two shift characters (LTRS, FIGS) allow for 26 letters, 10 numbers and punctuation.
  - International Telegraph Alphabet Number 2 (ITA2)

Digital Communications
Protocols And Codes

- ASCII - American National Standard Code for Information Exchange.
  - Seven bits
    - 128 Characters (2^7). No shift code.
    - Includes both upper and lower case characters
  - An Eighth bit (parity bit) is often included for error detection.
  - Some systems use the Eighth bit for data
    - 256 (2^8) Possible characters

Digital Communications
Digital Modes

- A digital mode consists of both a protocol and a method of modulation
  - Protocol – Set of rules that controls the encoding, packaging, exchanging and decoding of digital information.

Digital Communications
Digital Modes

- Digital protocols can be used to convey speech, video or data. Each specific use forms a different emission or mode
- The advantage of digital modes is that the signal and its information can be copied and retransmitted multiple times without introducing errors.

Digital Communications
Digital Modes

- CW
  - AM signal.
    - Two states, On and Off. (A1A emission)
  - Standard word "PARIS" used to measure speed
    - Contains 50 symbols (including spaces)
    - 1 WPM = 50 symbols / 60 sec = .83 baud
    - Baud = WPM / 0.83 = 1.2 x WPM
    - BW = WPM x 1.2 x K

      K = abruptness of keying waveform. (3 – 5)
    - 13 WPM code (K = 3.3)
      - » <u>BW = WPM x 1.2 x 3.3 = 13 x 4 = 52 Hz (51.48)</u>

Digital Communications
Digital Modes

- FSK / AFSK
  - Most amateur data transmissions use Frequency Shift Keying (FSK)
    - All data on HF uses FSK
    - The transmitter is shifted between two frequencies (Mark & Space frequencies) to create data symbols. The difference is the “shift”
      - Direct FSK. Shifting the transmitters oscillator frequency
        - » F1B, F1D emissions
      - Audio FSK (AFSK). Injecting two audio tones (SSB)
        - » J2B, J2D emissions
    - J2B or J2D generated by a correctly adjusted SSB transmitter appear identical to F1B, F1D

Digital Communications
Digital Modes

- FSK / AFSK modes require careful tuning so the tones of the signals are as close to exactly right angles as possible.
  - The display shows selective fading in which one or both of the tones is severely attenuated for a short for a short period as the ellipse shrinks.

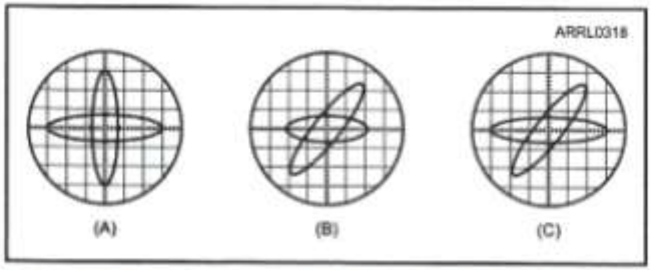

Figure 8-2 — The two tones of an FSK or AFSK signal are represented as a pair of ellipses on a crossed-ellipse display. For the best copy, the signal should be tuned so that the ellipses are of equal size and at right angles as in (A). Displays such as at (B) and (C) indicate a mistuned signal.

Digital Communications
Digital Modes

- FSK / AFSK
  - Bandwidth related to shift and data rate
    - BW = (K x Shift) + B

BW- Bandwidth

K - Constant relating to signal distortion and transmission path. K = 1.2

Shift – Frequency in Hz

B – Baud

<u>170Hz shift, 300 baud, ASCII</u>, transmitted as J2D emission

<u>BW = (1.2 x 170 Hz) + 300 = 0.5 KHz (504Hz)</u>

<u>4800Hz shift, 9600 baud, ASCII</u>, transmitted as F1D emission

<u>BW = (1.2 x 4800 Hz) + 9600 = 15360 Hz = 15.36 kHz</u>

Digital Communications
Digital Modes

- PSK
  - PSK31.
    - G3PLX developed PSK31 for real time keyboard-to-keyboard QSOs
    - Phase-shift keying (PSK), Data Rate 31.25 baud (31)
    - 128 character ASCII code
    - J2B emission type
    - Varicode
      - "00" represents gap between characters
      - "00" never appears in a character
    - 50 wpm typing rate requires a 32 bit/s transmission rate.
    - <u>Bandwidth is minimized by the special sinusoidal shaping of the transmitted data symbols.</u>
    - <u>Narrowest of all HF digital modes used by amateurs, including CW</u>

Digital Communications
Digital Modes

- HF Packet
  - Same AX.25 protocol as on VHF
  - HF Packet uses FSK at 300 baud
    - Limited to 300 baud by regulation to control bandwidth
  - The length of AX.25 packets (40 bytes) and the hostile environment of HF propagation make HF packet difficult at times.
  - When conditions are good and fading is mild, HF Packet has a higher data rate than RTTY, AMTOR, or PSK31

Digital Communications
Digital Modes

- PACTOR
  - The Original (PACTOR-I)
    - Developed by DL6MAA & DF4KV
    - Designed to overcome shortcoming of AMTOR and HF Packet
    - Performs well under weak signal and high noise conditions

Digital Communications
Digital Modes

- PACTOR-II AND PACTOR-III (in use today)
  - Supports the transfer of binary files
  - Email over HF via Winlink system.
    - System of modes and protocols and internet services
    - Does not support keyboard-to-keyboard or “chat”
  - Uses ARQ (Automatic Repeat Request) to correct errors
  - Auto evaluate conditions and adjust speed
  - Highest data rate of any HF digital mode. > 5kbps

Digital Communications
Digital Modes

- Multi-Mode Protocols
  - MFSK16
    - Frequency Shift Keying (FSK). 16 Tones
    - <u>Bandwidth of 316 Hz</u>. Data Rate of 63 bps
    - Error Correction
    - Varicode
  - MT63
    - Wider bandwidth. 1 kHz typically
    - 64 Tones
    - More tolerant of tuning errors than MFSK16

Digital Communications
Digital Modes

- WSJT Protocol
  - Developed by K1JT for demanding VHF/UHF weak signal work such as EME
  - Five Modes
    - FSK441 for meteor scatter
    - JT65 for EME (Earth Moon Earth)
      - Decodes signals that have a very low signal to noise ratio, even signals below the noise level
    - JT6M for meteor scatter on 6 meters
    - EME Echo for measuring your own signals
    - CW for 15 WPM EME QSOs

Digital Communications
Digital Modes

- Transmitting Digital Mode Signals
  - For good performance, Pay attention to transmitted signal quality
  - AFSK
    - Excessive signal level can overdrive the modulator or RF amplifier creating intermodulation distortion and spurious signals
    - Follow Manufacturer's instructions on setting transmitter controls, especially ALC and mic gain

Digital Communications
Digital Modes

- Transmitting Digital Mode Signals
  - "On-Air" check
    - Measuring your own digital signal can be done by transmitting into a dummy load, receiving the signal on a second receiver, and feeding the audio into the sound card of a computer running a demodulation program for that mode.

Spread Spectrum Techniques

- Spread Spectrum spreads the signal over a very wide bandwidth by rapidly varying the carrier frequency of the signal in a predefined sequence.
  - Signal bandwidth is increased by factors of 10 to 10,000 using the spreading code to vary the signals frequency.
  - Spread-spectrum receiver can reject strong undesired signals.
    - The receiver uses the spreading code (algorithm) to “de-spread” the signal which suppresses non-spread conventional signals.

Spread Spectrum
Techniques

- Dilution of the signal across many frequencies causes spread spectrum signals to appear as wideband noise to a conventional receiver
  - Signal may be below the noise floor of a conventional receiver.
  - Power on any given frequency within the spectrum is very low.

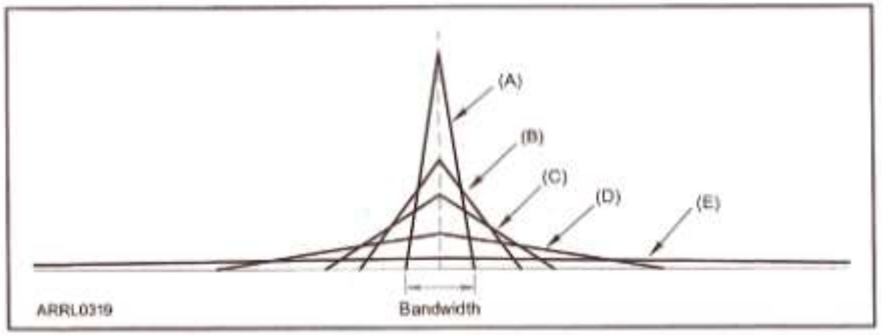

Figure 8-3 — A graphic representation of the distribution of power as the signal bandwidth is increased. The unspread signal (A) concentrates most of its energy near a center frequency. As the bandwidth increases (B), the power near the center frequency falls. At C and D, the energy is distributed wider and wider across the spread signal's wider bandwidth. At E, the signal energy is spread over a very wide bandwidth and there is little power at any one frequency.

Spread Spectrum
Techniques

- The use of different spreading codes allows several systems to operate independently and share the frequencies.
  - Code Division Multiple Access (CDMA)
    - Used by mobile phone systems
- Properly chosen spreading parameters results in very little interference to conventional signal users.

Spread Spectrum
Types of Spread Spectrum

- Frequency Hopping
  - The frequency of the transmitted signal is rapidly changed according to a particular sequence also used by the receiving station.

- Direct Sequence
  - A high speed binary bit stream is used to shift the phase of the modulated RF carrier.
    - Typically used to transmit digital information.

Digital Communications
Error Detection and Correction

- Error Detection
  - Information describing the data is sent along with the original data.
    - Parity bit of ASCII data – limited error checking
    - AX.25 protocol uses checksums
      - Originally was the sum of all data
      - Evolved to cyclical redundancy check (CRC)
  - Receiving system compares the data received to the checksum values.

Digital Communications
Error Detection and Correction

- Error Correction
- ARQ (Automatic Repeat Request)
  - Receiving station sends NAK, Not Acknowledged, back to transmitting station.
    - Data is retransmitted until receiving station sends ACK, Acknowledged.
- FEC (Forward Error Correction)
  - Extra data is sent in the packet to allow the receiving station to detect and correct some errors.

Amateur Television

- Many Amateurs enjoy sending and receiving “real” television signals via Amateur TV (ATV).
- Public service events
  - Status reporting
  - Remember…no “broadcasting”
- Emergency and disaster relief operations
  - Damage assessment
  - Status reporting
- Mobile platforms (RC planes, Balloons, etc.)

Amateur Television
Fast Scan

- Fast-scan TV (FSTV)
  - Full motion video
  - Uses the same technical standards as broadcast TV

System Components

- Camera – Standard video out
- Microphone
- TV / Monitor – Standard video in
- ATV Transmitter (amplifier)
- Antenna

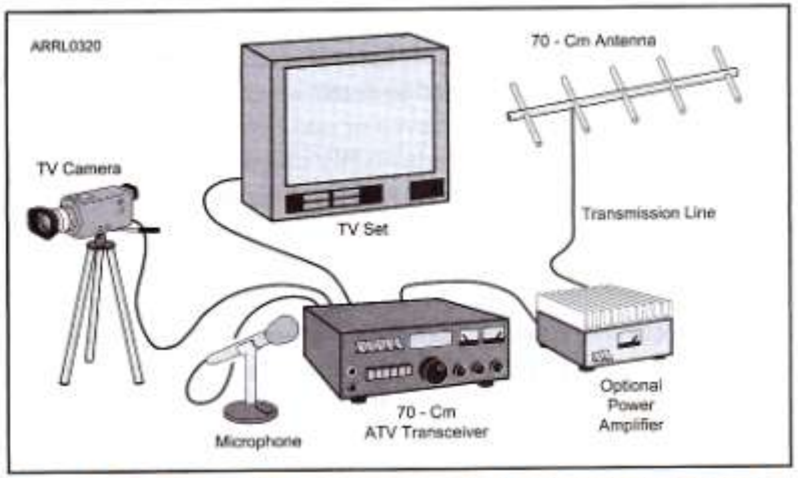

Figure 8.4 — A basic ATV station consists of a camera to produce video, an AM or FM amateur television transceiver (or transmitter and receive converter), an optional amplifier, a directional antenna with gain, and a commercial TV receiver (the receive converter is built into the transceiver).

Amateur Television
Fast Scan

- Image Signal Definitions
  - The process of acquiring the image is called *scanning*.
  - To scan an image, some type of light sensor separates the image into horizontal lines called *scan lines*.
  - The set of video and control signals that define the image is called the *raster*.

Amateur Television
Fast Scan

– The way the raster's video and control signals are combined to transmit and reassemble the image is defined by the video standard.
  - US Amateurs use the NTSC (National Television Standard Committee) standard.
  - The PAL and SECAM standards are used in other countries
  - These standards are similar but not compatible with each other.

Amateur Television
Fast Scan

- NTSC Standard
  - 525 horizontal scan lines comprise a frame
  - 30 frames are generated each second (30 Hz)
  - Each frame consists of two fields, each containing 262 ½ lines.
  - 60 fields generated per second (60 Hz)
  - Scan lines from one field fall between lines from the next field. *Interlacing*
    - Reduce flicker
    - Improves motion smoothness
    - Reduce bandwidth while maintaining quality

Amateur Television
Fast Scan

- 525 scan lines are numbered from top to bottom
  - One field contains the odd numbered lines
  - The alternate field contains the even numbered lines.
  - Field one scanning starts at the top left.
  - The electron beam sweeps across the image to the right side traveling slightly downward.
  - At the end of the line the beam is turned off or *blanked, and* returned to the left side.
  - At the end of 262 ½ scan lines the beam is blanked and returned to the top of the image.
  - Scanning of field two begins top center with the beam now traveling between the field one lines.
  - To preserve detail, the horizontal and vertical oscillators are synchronized by the video sync pulses.

Amateur Television
Fast Scan

- Scanning movement

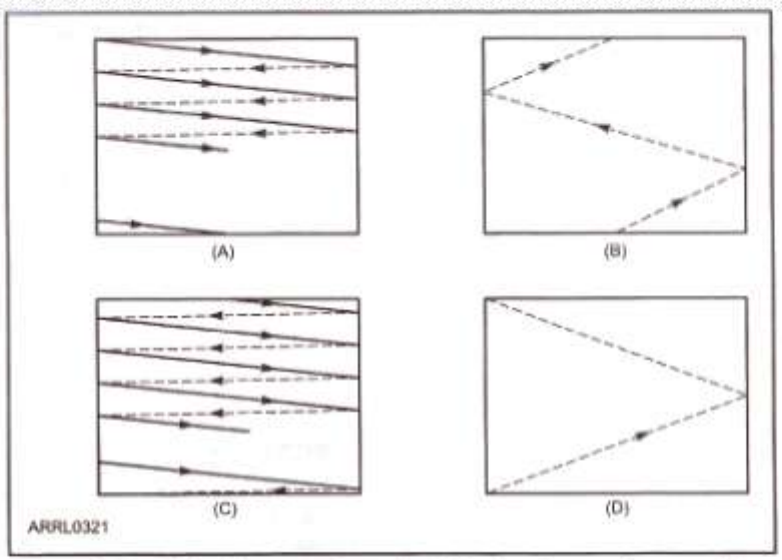

Figure 8-5 — This diagram shows the interlaced scanning used in TV. In field one, 262½ lines are scanned (A). At the end of field one, the electron scanning beam is returned to the top of the picture area (B). Scanning lines in field two (C) fall between the lines of field one. At the end of field two, the scanning beam is again returned to the top, where scanning continues with field one (D).

Amateur Television
Fast Scan

- Video Signal Definitions
  - The signal that carries the image and display coordination information is called baseband video or composite video. ANSI RS-170.
    - Sync signals are negative
      - Vertical Sync pulse – New field
      - Horizontal Sync pulse – New Scan Line
    - Video is positive. Level determines brightness (Luminance).
      - Voltage between sync tip and video white 1-V pp

Amateur Television
Fast Scan

- Monochrome video waveform

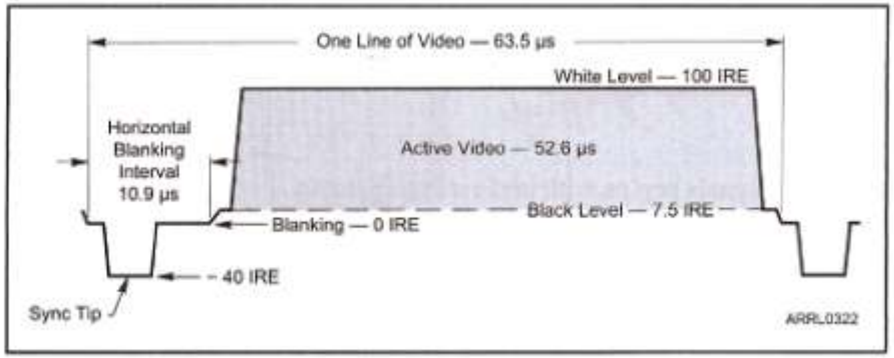

Figure 8-6 — RS-170 monochrome waveform for one video line. A full NTSC video frame consists of 525 video lines organized as two interlaced fields. Each field takes 1/60th of a second to transmit, so that 30 frames are transmitted every second. IRE units are used to measure the relative amplitude of the different parts of the video signal

Amateur Television
Fast Scan

- Composite and RGB Video
  - In a composite color video signal, all of he information is contained in a single waveform.
    - The color (chroma) information is combined with the luminance buy using a chrominance subcarrier signal. The chroma burst syncs the signals.
  - Color video can be sent as three separate monochrome signals (RGB video). Creates cleaner, sharper images.

Amateur Television
Fast Scan

- Composite video waveform

- Standard TV signal spectrum

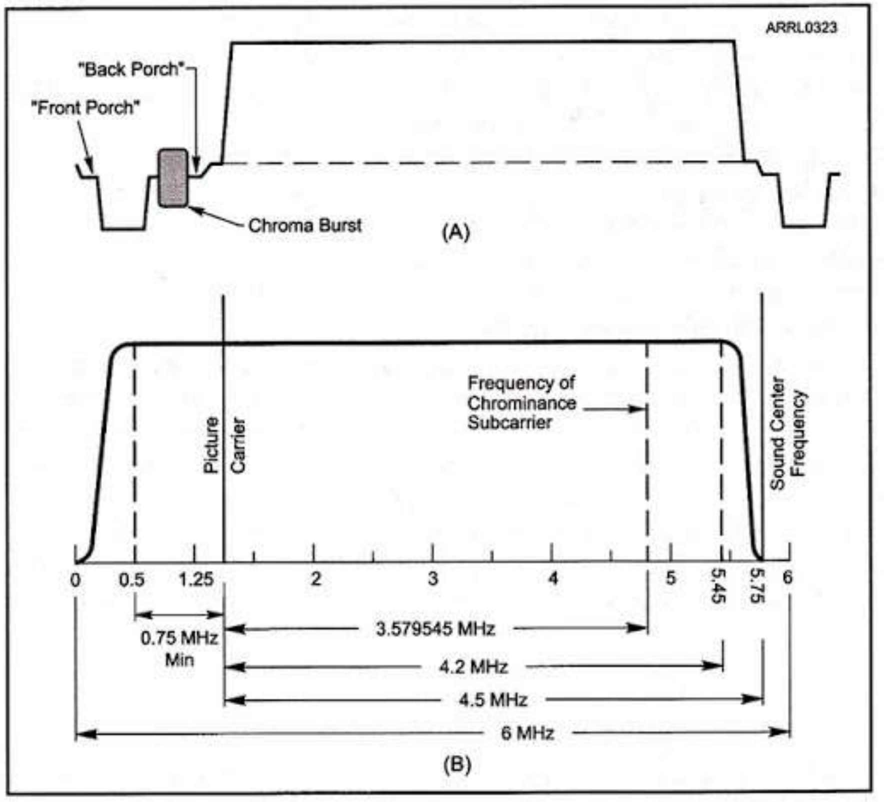

Figure 8-7 — Composite video (A) adds the color burst at the start of each line to synchronize the chroma circuits. (B) shows the spectrum of a standard broadcast TV signal. ATV may or may not use the FM subcarrier for sound.

Amateur Television
Fast Scan

- Modulated Television Signals
  - AM transmission.
    - Video Inverted. Sync is positive, Video is negative.
      - More stable image with weak signals.

Amateur Television
Fast Scan

- RF ATV Characteristics
  - Bandwidth of about 4 MHz
  - Wide bandwidth necessary for full-motion
  - Only permitted in 420-450 band and higher
  - Typical range of 20 miles with 20-100 watts
  - Avoid interfering with weak signals (432 MHz) and repeaters (above 442 MHz)
  - Vestigial Sideband usually used (VSB)
    - Amplitude modulation with one complete sideband and a portion of the other.
    - VSB reduces bandwidth while allowing for simple video detector circuitry.

Amateur Television
Fast Scan

- FM Television
  - Bandwidth of 17 to 21 MHz
  - Most FM ATV operates in 1.2, 2.4, and 10.25 GHz bands because of the greater bandwidth requirement.
  - Receiving systems are more complex than with AM
  - AM gives better weak signal performance
  - FM has better image quality on strong signals

Amateur Television
Fast Scan

- The Audio Channel
  - Separate VHF or UHF audio link
  - Frequency Modulated sub-carrier 4.5 MHz above the TV image (Commercial TV method)
  - Frequency modulation of the video carrier

Amateur Television
Slow Scan

- Image modes used on HF
  - Facsimile or fax (rarely used)
  - Slow-Scan television (SSTV)
    - Narrower bandwidth than Fast-Scan TV
    - Still images only

Figure 8-9 — This screen shot shows an SSTV program that uses the computer sound card to send and receive images.

Amateur Television
Slow Scan

- SSTV System
  - Computer and software generates audio tones that represent the image to be transmitted, and decodes received images.
  - SSTV is 100% duty cycle transmission.

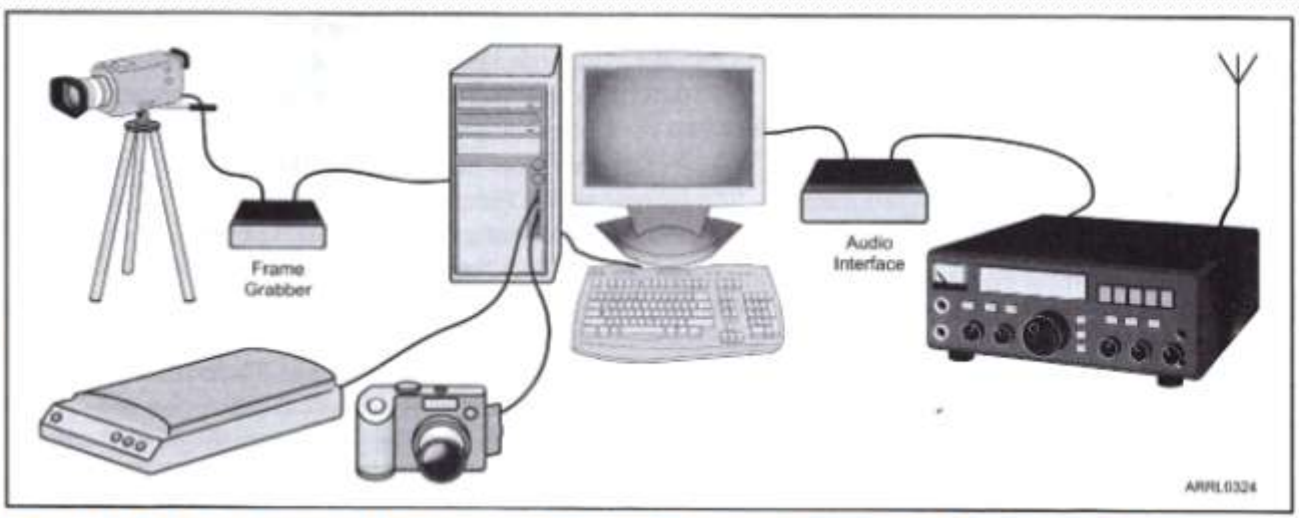

Figure 8-8 — The most common SSTV station uses a video or digital camera, or an image scanner, to generate still images. Software then processes the image and converts it to audio tones that are input to an SSB transmitter.

Amateur Television
Slow Scan

- Analog SSTV Signal
  - Like FSTV, the image is divided into san lines and frames.
  - Instead of voltage levels as video and sync signals, SSTV uses varying tone frequencies. This allows SSTV to be transmitted using SSB modulation.
    - Bursts of 1200 Hz tones signify new lines
    - Luminance transmitted as a tone of varying frequency.
      - 1500 Hz (black) to 2300 Hz (white)

Amateur Television
Slow Scan

– Monochrome black and white SSTV image takes 8 seconds to transmit one frame and has only120 scan lines.

Table 8-3
Black-and-White SSTV Standards

Frame time	8 seconds
Lines per frame	120
Time to send one line	67 ms
Duration of horizontal sync pulse	5 ms
Duration of vertical sync pulse	30 ms
Horizontal and vertical sync frequency	1200 Hz
Black frequency	1500 Hz
White frequency	2300 Hz

Amateur Television
Slow Scan

– Most SSTV operators today send color
  - Several modes. 120, 128, 240 or 256 scan lines.
  - Transmit time 12 seconds to 4 minutes.
  - The 128 line and 256 line formats are the most popular.

Table 8-4
Color SSTV Standards

Format	*Name*	*Time (sec)*	*Lines*
Wraase SC-1	24	24	128
	48	48	256
	96	96	256
Martin	M1	114	256
	M2	58	256
	M3	57	128
	M4	29	128
Scottie	S1	110	256
	S2	71	256
	S3	55	128
	S4	36	128

Amateur Television
Slow Scan

- The bandwidth of a color SSTV signal is approximately 3 KHz. Higher than for monochrome.
- For receiving equipment and software to discern the mode of the SSTV image, a code called Vertical Interval Signaling (VIS) is transmitted with each image frame.

Amateur Television
Slow Scan

- Digital SSTV
  - Digital Radio Mondiale (DRM) protocol
    - “Digital World Radio”
      - Developed by shortwave broadcasters to send digitally encoded programs with much higher audio quality.
    - Amateurs adapted DRM to send digitized images.
    - Signals generated and decoded with software. Only a SSB receiver and a suitable computer is needed to decode SSTV using DRM.
    - Amateur DRM signals are restricted to 3 KHz.

Amateur Television
Slow Scan

- SSTV Operating
  - Permitted in the phone segment of all bands.
  - SSTV signal bandwidth must be no greater than that of a phone signal using the same modulation type.
  - Most popular bands for SSTV are 20 and 75 meters.
  - SSTV operating procedures similar to SSB.

Receiver Performance

- It is important to be able to measure and evaluate receiver quality.
  - Successful communications depends on quality reception of signals.
    - Free of noise and distortion
    - Ignore unwanted signals
    - Sensitive to the weakest signals

Receiver Performance
Sensitivity and Noise

- One basic receiver specification is sensitivity or Minimum Discernible Signal (MDS).
  - MDS of a receiver is the strength of the smallest discernible input signal.
  - Depends on noise figure and bandwidth.
  - MDS also called the receiver's noise floor.
    - Signal that produces same audio level as the receivers noise.
  - The lower the MDS the more sensitive the receiver.

Receiver Performance
Sensitivity and Noise

- MDS often expressed in dBm
  - Decibels with respect to one milliwatt
    - 0 dBm is the same as 1 mw, +10 dBm 10 mw, etc.
- MDS also expressed as μV.
  - An MDS of 0.5 μV equals and MDS of -113 dBm.
    - Practical MDS on the HF bands.
    - The theoretical noise at the input of an ideal receiver, with an input filer bandwidth of 1 Hz, is -174 dBm/Hz at room temperature.
- Atmospheric noise is the primary source of noise in and HF receiver and therefore the limiting factor for sensitivity of receivers on the HF bands.

Receiver Performance
Sensitivity and Noise

- A receiver bandwidth of 1 HZ is impractical but is used as a reference.
  - For the filter width the receiver uses you can calculate the theoretical MDS.
    - MDS for a receiver with a -174 dBm/Hz noise floor if a 400 Hz filter band-width is used.

10 log (400 Hz) = 26 db

-174 dBm + 26 db = -148 dBm

Receiver Performance
Sensitivity and Noise

- Noise Floor and Signal-to-Noise ratio
  - Noise figure is a “figure of merit” for the receiver.
    - Ratio in dB of the noise generated by the receiver itself to the theoretical MDS.
    - The higher the noise figure the more noise generated within the receiver.
    - Higher noise floor.
    - Lower noise figures are more desirable
      - Low-noise UHF preamp might have a noise figure of 2dB.

Receiver Performance
Sensitivity and Noise

– Receiver’s internal noise degrades the noise floor, or raises the power that actual signals must have to be heard.
– You can calculate the actual noise floor.
  • Actual Noise Floor = Theoretical MDS + noise figure
– Noise figure of a receiver is related to signal-to-noise ratio (SNR) or the input and output signals.
– <u>Lowering a receiver’s noise figure lowers it noise floor and improves weak signal sensitivity</u>.
– Another type of signal to noise ratio is signal-to-noise-and-distortion (SINAD).

Receiver Performance
Selectivity

- The perfect receiver can tune any frequency and reject every signal except the one you want to receive.

- Selectivity
  - The ability to select a specific signal.
  - Selectivity determined by bandwidth the receiver's entire filter chain from front end to audio output.
  - Superheterodyne receivers have several filters in the signal path.

Receiver Performance
Selectivity

- Band-pass front end filters
  - Provide front end selectivity
  - Reject strong near out of band signals
- Preselector
  - Tunable input filter that passes the desired frequency.
  - Increases rejection of out of band signals.
- Band pass filters and preselectors both are effective in eliminating image signal interference.
- IF amplifier filters.
  - LC, quartz crystal, ceramic resonator.
  - Reject unwanted mixing products and prevent spurious signals from slipping into the signal path.

Receiver Performance
Selectivity

- Increasing a superheterodyne receiver's IF frequency improves selectivity. As the IF is increased the frequency at which image responses occur becomes farther from the desired signal and easier to filter out.

- Example:
  - IF of 455Khz. Signal on 14.300 MHz

    BFO tuned to 14.3 + .455 = 14.755 MHz
  - Image on 15.210 received because 15.210 – 14.755 MHz = 0.455 MHz.
  - If we raise the IF to 9 MHz, BFO is 14.3 + 9 = 23.3 MHz and the image frequency would be 23.3 + 9 MHz. Farther away from the desired signal and easier to filter.

Receiver Performance
Selectivity

- At the input to each IF stage a roofing filter is often used.
  - Usually crystal filters.
  - Bandwidth wider than the widest signal to be received.
  - Attenuates strong signals near the receive frequency.

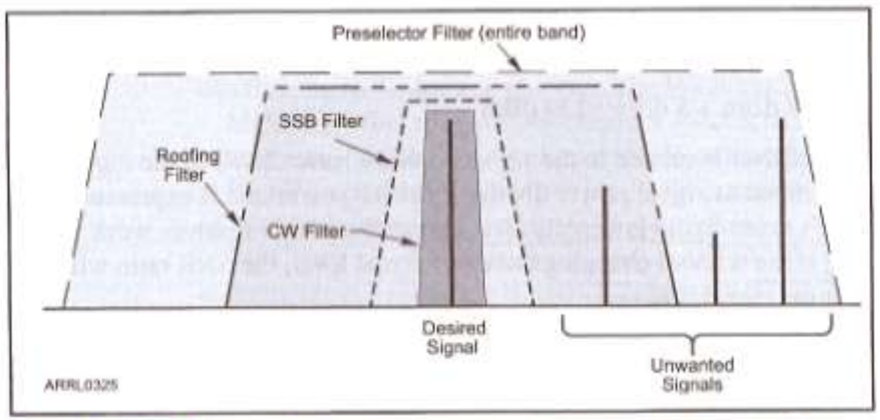

Figure 8-10 — A typical multiple-conversion superheterodyne receiver has several stages of filtering. Preselector filters reject out-of-band signals. Roofing filters at the input to each IF further restrict receiver bandwidth, attenuating strong in-band signals that might overload the IF amplifiers. In the final IF stage, single-signal filters are used to select just the desired signal.

Receiver Performance
Selectivity

- In the final IF, narrow filters used to select on signal from the many that may be present.
  - Crystal (most common)
  - Mechanical
  - Filter must be appropriate for the desired signal.
    - Examples: RTTY 300 Hz, SSB, 2.4 KHz
  - Narrower filters improve selectivity but limit fidelity and the ability to detect nearby signals.
  - Wider filters are more comfortable to listen to but <u>allow undesired signals on nearby frequencies to be heard as well.</u>

Receiver Performance
Dynamic Range and Intermodulation

- Dynamic Range
  - The ability of a receiver to tolerate strong signals outside of the normal passband.
  - The ratio between the MDS and the largest input signal that does not cause audible distortion products.
  - Dynamic range measurements are in dB.
- Blocking Dynamic Range (BDR)
  - A strong input signal can cause the receiver to no longer respond linearly and gain to drop.
  - Causes weaker signals to appear to fade
  - Gain compression or blocking.

Receiver Performance
Dynamic Range and Intermodulation

– Blocking may be observed as desensitization or desense…the reduction in apparent strength of a desired signal caused by a nearby strong interfering signal.
– Blocking Dynamic Range (BDR) is the difference in dB between the noise floor and the level of an incoming signal which will cause 1 dB of gain compression.
– It may be possible to reduce the desensitization by using IF filters to reduce the receiver's RF bandwidth and reject the strong signals.

Receiver Performance
Dynamic Range and Intermodulation

- Intermodulation (IMD)
  - A perfectly linear receiver will produce an output signal with a strength that changes exactly the same as the input signal. This is called first order response.
  - As the signal strength increases the receiver's response becomes nonlinear and IMD products are created.

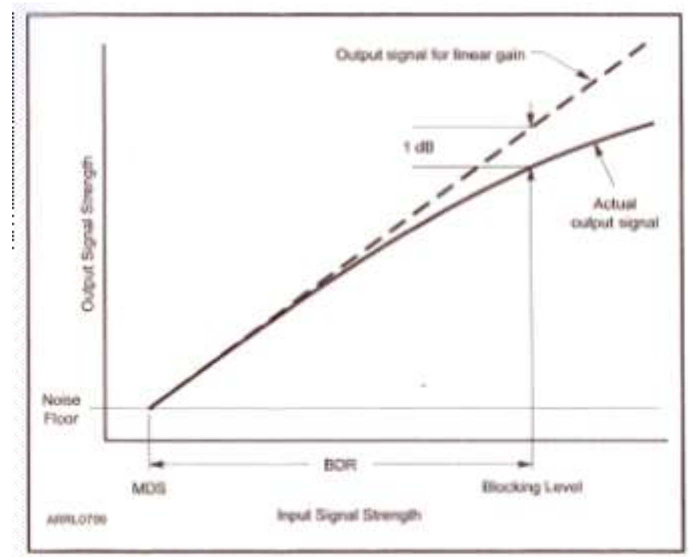

Figure 8-11 — Gain compression occurs when the input signal is too strong for the receiver to develop full gain. Blocking Dynamic Range (BDR) is measured in dB from MDS to a level at which the input signal strength causes a 1 dB drop in receiver gain, called the blocking level.

Receiver Performance
Dynamic Range and Intermodulation

– IMD products are created at frequencies which are the sum and differences of the input signals and their harmonics.
– The frequencies of second-order IMD products caused by signals that are close together are far from the frequency of either input signal and are generally not a problem if caused by signals within an amateur band.

Receiver Performance
Dynamic Range and Intermodulation

– If the signals causing the IMD products are close together, such as in the same amateur band as the desired signal, the subtractive IMD products could be very close to the desired signal.

- Third Order IMD Product Frequencies

$f_{IMD1} = 2f_1 + f_2$

$f_{IMD2} = 2f_1 - f_2$

$f_{IMD3} = 2f_2 + f_1$

$f_{IMD4} = 2f_2 - f_1$

– Third-Order IMD performance of a receiver is an important specification.

Receiver Performance
Dynamic Range and Intermodulation

– Example
  - What are the likely frequencies for a second strong signal that could combine with the one on 146.52 MHz to produce the IMD product you hear on 147.70 MHz ?

$f_{IMD2} = 2f_1 - f_2$

$f_2 = 2f_1 - f_{IMD2}$

$f_2 = 2 \times 146.52 – 147.70$

$f_2 =$ 146.34 MHz

$f_{IMD4} = 2f_2 - f_1$

$f_1 = (f_{IMD2} + f_2) / 2$

$f_1 = (146.70 + 146.52) / 2$

$f_1 =$ 146.61 MHz

Receiver Performance
Dynamic Range and Intermodulation

- It may not be practical to filter out strong input signals because they are in-band signals.
  - Possible remedies
    - Use a receiver with higher dynamic range.
    - Use an attenuator at the signal input.
    - Reduce RF gain
    - Use a roofing filter.

Receiver Performance
Dynamic Range and Intermodulation

– Intercept Point
  - The input signal power at which the level of the distortion products equals the output level for the desired signal is the receiver’s intercept point.
    - – Example
      - » <u>A 40 dBm third-order intercept point means the a pair of 40 dBm signals would produce and IMD product of same 40 dBm level.</u>

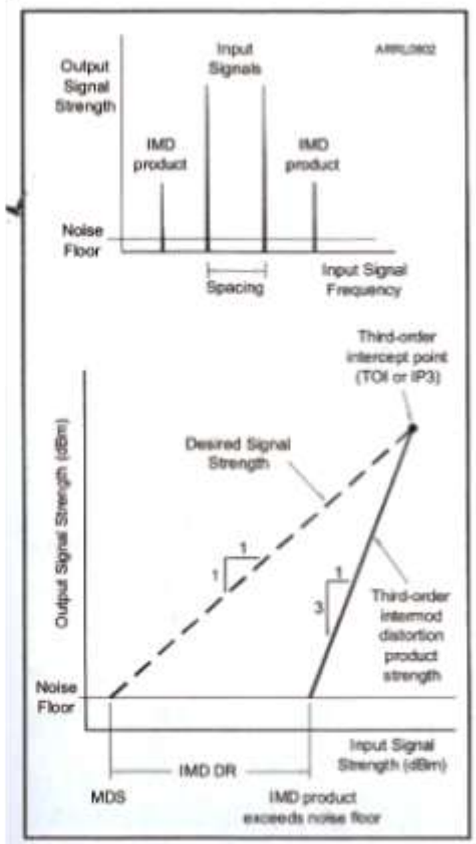

Figure 8-12 — Receiver output power for a desired signal and for third-order distortion products varies with changes of input signal power. The input signal consists of two equal-power sine-wave signals. Higher intercept points represent better receiver IMD performance.

Receiver Performance
Dynamic Range and Intermodulation

- Intermodulation distortion dynamic range measures the ability of the receiver to avoid generating IMD products. When input signal levels exceed the IMD dynamic range, IMD products will begin to appear along with the desired signal.

- <u>If a receiver has poor dynamic range, cross modulation or IMD products will be generated and desensitization (blocking) from strong adjacent signals will occur.</u>

Receiver Performance
Phase Noise

- Phase noise has become more apparent as receiver improvements have reduced the noise floor and increased dynamic range.

- Caused by PLL or DDS synthesizers continually adjusting their frequency as compared to a reference.

- Excessive phase noise in a receiver local oscillator allows strong signals on nearby frequencies to interfere with the reception of a weak desired signal.

Receiver Performance
Capture Effect

- FM receivers exhibit an effect know as capture effect. The loudest signal received even if it is only a few dB stronger than the other signals on the same frequency will be the only signal demodulated, blocking all weaker signals.
  - Can be an advantage if you are trying to receive a strong station and there are weaker stations on the same frequency.