Contents

Image Communications

This supplement covers two popular communication modes that allow amateurs to exchange still or moving images over the air. Advances in technology have made image communications easier and more affordable, resulting in a surge of interest. Amateurs use two forms of image communication; *Fast-Scan TV* (FSTV), usually referred to as *Amateur TV* (ATV), and *Slow Scan TV* (SSTV). ATV is a full-motion video mode and SSTV sends individual still frames. Due to bandwidth restrictions, ATV is found on the 70 cm and higher frequency bands. SSTV can be transmitted over a voice channel.

ATV and SSTV can be used by high-altitude balloons or rockets and satellites to transmit images on VHF and UHF. See the **Amateur Radio Data Platforms** chapter for examples of how image transmissions are part of temporary experiments and radio-controlled aircraft and mobile platforms. The International Space Station often transmits ATV and SSTV images as well. See **ariss.org** for information on what image transmission systems are active.

Detailed descriptions of the modulations used for each mode are available in the **Modulation** chapter. Images sent via amateur mesh networks are not covered in this chapter. See the **Digital Protocols and Modes** chapter for more information about mesh networks.

ATV techniques are covered by Jim Andrews, KH6HTV, with additional contributions from previous editions by Tom O'Hara, W6ORG. SSTV techniques are described by Wayne Mueller, W1QC, based on material originally developed by Larry Peterson, AA9TT, in previous editions.

1 Fast-Scan Amateur Television (ATV) Overview

ATV adds a visual aspect to amateur radio communications. Instead of just talking about home-brew projects, amateurs can show them off in much more detail to fellow hams. For example, **Figure 1** shows hams enjoying an ATV net. ATV can also televise local ham club meetings and is educational and exciting to younger hams and potential hams. There are even ATV repeaters to extend the range of ATV communications. For a newcomer to ATV, it is best to first connect with other hams in the area using ATV and find out what activity there is locally.

A more complete treatment of ATV is contained in the author's publication AN-55a, ATV Handbook — an Introduction to Amateur TV which is available on ARRL web site at: **www.arrl.org/atv-fast-scan-amateur-television** under the title "Introduction to Amateur Digital Television." The author provides numerous other helpful papers and documents on ATV at

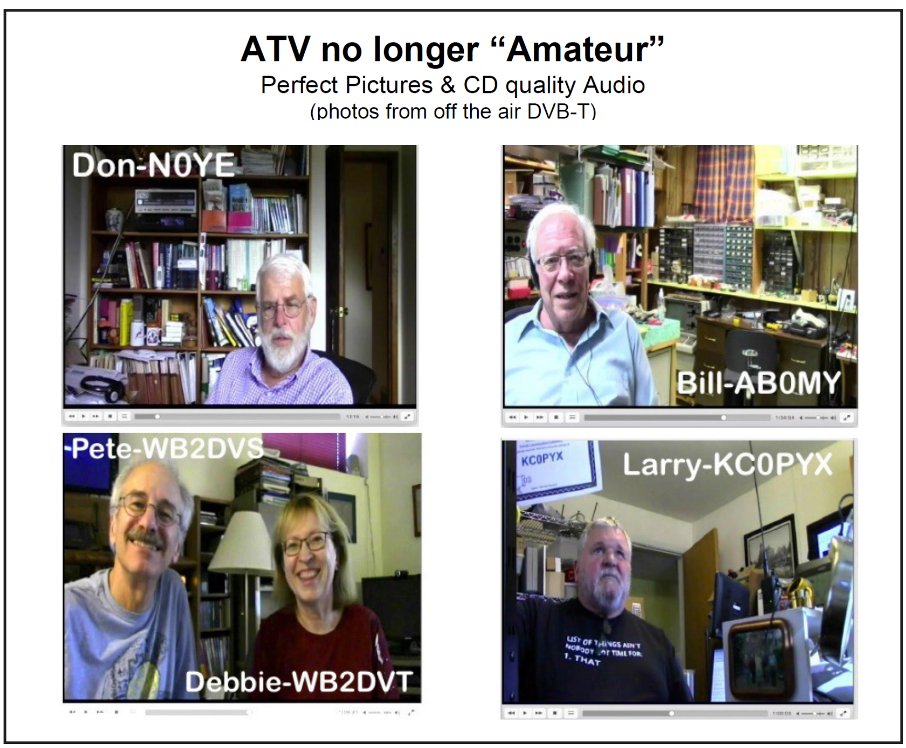


Figure 1 — A local net being conducted via ATV.

kh6htv.com/application-notes. The history of television technology is well-covered online with an overview at **www.britannica.com/technology/television-technology/Basic-principles-of-compatible-colour-The-NTSC-system**. A list of suppliers of ATV equipment, including receivers, is included at the conclusion of this section.

1.1 ATV and Public Service

ATV has many uses for public service. Many public service groups support local parades, races, and other large public events. Providing live video coverage to the event organizers can be extremely valuable. Severe storm monitoring and trackingis enhanced by live video. ATV video has also been used to cover natural disasters such as forest fires, floods, and tornadoes. **Figures 2** and **3** show typical ATV public service activities.

Live video transmitted from an incident site to an Emergency Operations Center (EOC) provides a valuable addition to disaster communications. A real-time view of the incident scene can give commanders an immediate feel for what is going on. Using ATV, they can zoom in on a critical component rather than rely solely on descriptions relayed by voice or data. While ATV reduces the need for voice traffic repeats and clarifications, it also provides full duplex audio, allowing for simultaneous communication to and from the EOC. To do so, the ATV transmitting station in the field talks on the sound subcarrier, and the EOC talks — at the same time — on 2-meter FM voice. Races, parades, and other public service events benefit from a ham volunteer transmitting video back to medical and emergency response personnel to inform them of what is happening at critical locations.

Figure 2 — A low power 70 cm ATV transmitter can be used to show conditions on a racecourse or at aid stations. This setup delivered video over a 2-mile path.

Figure 3 — An EOC benefits from having real-time ATV images available to emergency managers and public safety officials.

2 ATV Systems

There are two basic systems used for ATV: analog and digital. Regardless of which type of ATV you're interested in, the appropriate receiving and transmitting equipment are very similar. A basic AM 70 cm ATV station is shown in **Figure 4**. The most common transmitter types are a self-contained, analog ATV transmitter and a digital TV modulator driving an RF power amplifier. An audio/video source is connected to the transmitter or modulator's audio/video input. Sources can be a camcorder, video camera, digital camera, VCR, DVR, or any device with RS-170 or CVBS video output. A separate audio source may also be used.

Older analog TV receivers can be used to receive analog ATV either with a frequency converter from the 70 cm band to over-the-air channels or directly on cable TV channels 57 – 60 that are within the amateur 70 cm band. (Channel 61 is also in the 70 cm amateur band but is usually in use by voice repeater systems.) Digital ATV also uses commercial broadcasting technology (see below) and the ATSC and CATV DTV modes can be received directly on a US home TV receiver, although DVB-S and DVB-T offer better performance. More about each technology is covered in the following sections.

2.1 Analog ATV

Analog ATV uses the same technology originally used for analog TV broadcasting. The original NTSC (National Television System Committee) standard developed in the late 1930s used the technology of that era, in other words AM. FM was just becoming practical at that time, so it was used for carrying the audio portion of the NTSC TV signal. FM was also used for the microwave links to carry TV signals long distances across the nation.

NTSC specifies a composite video signal with 525 horizontal scan lines at a 30 Hz frame rate. An analog TV display first sweeps from left to right, then is rapidly reset back to the left side of the screen and moves down one line. (See **Figure 5A**.) When the scan reached the bottom of the screen, it would then be reset vertically to the top of the screen and a new frame would commence.

AM ATV

The NTSC composite video signal (see Figure 5B) used to modulate an AM carrier is a 1 V_{P-P} signal into 75 ohms. Horizontal scan lines are organized in two interlaced fields that make up a single frame of 525 lines with 262.5 lines per field. Fields occur at 60 Hz and complete frames at 30 Hz. Only 480 of the lines are visible on the display with the remainder used for data information or blanked during the vertical retrace interval. Each line of video begins with the horizontal sync pulse to reset the horizontal trace from the previous line followed by the analog luminance or brightness (gray scale) picture information for the current line. After a complete field has been displayed, a longer duration vertical sync pulse then resets the trace from the bottom to the top of the monitor screen. Horizontal sync pulses occur at 15 kHz and the vertical sync at 60 Hz. Color information is also embedded in the video signal referenced to the 3.58 MHz color burst signal (for more details, see the **Modulation** chapter).

The video signal's spectrum extended from the low 60 Hz sync rate of the vertical pulses up to an upper luminance (i.e., monochrome brightness) bandwidth of 4.2 MHz. When broadcast by the NTSC system, the composite, 4.2 MHz bandwidth video signal first AM modulates an RF carrier. This results in a double sideband AM signal occupying at least 8.4 MHz of bandwidth. To conserve band-

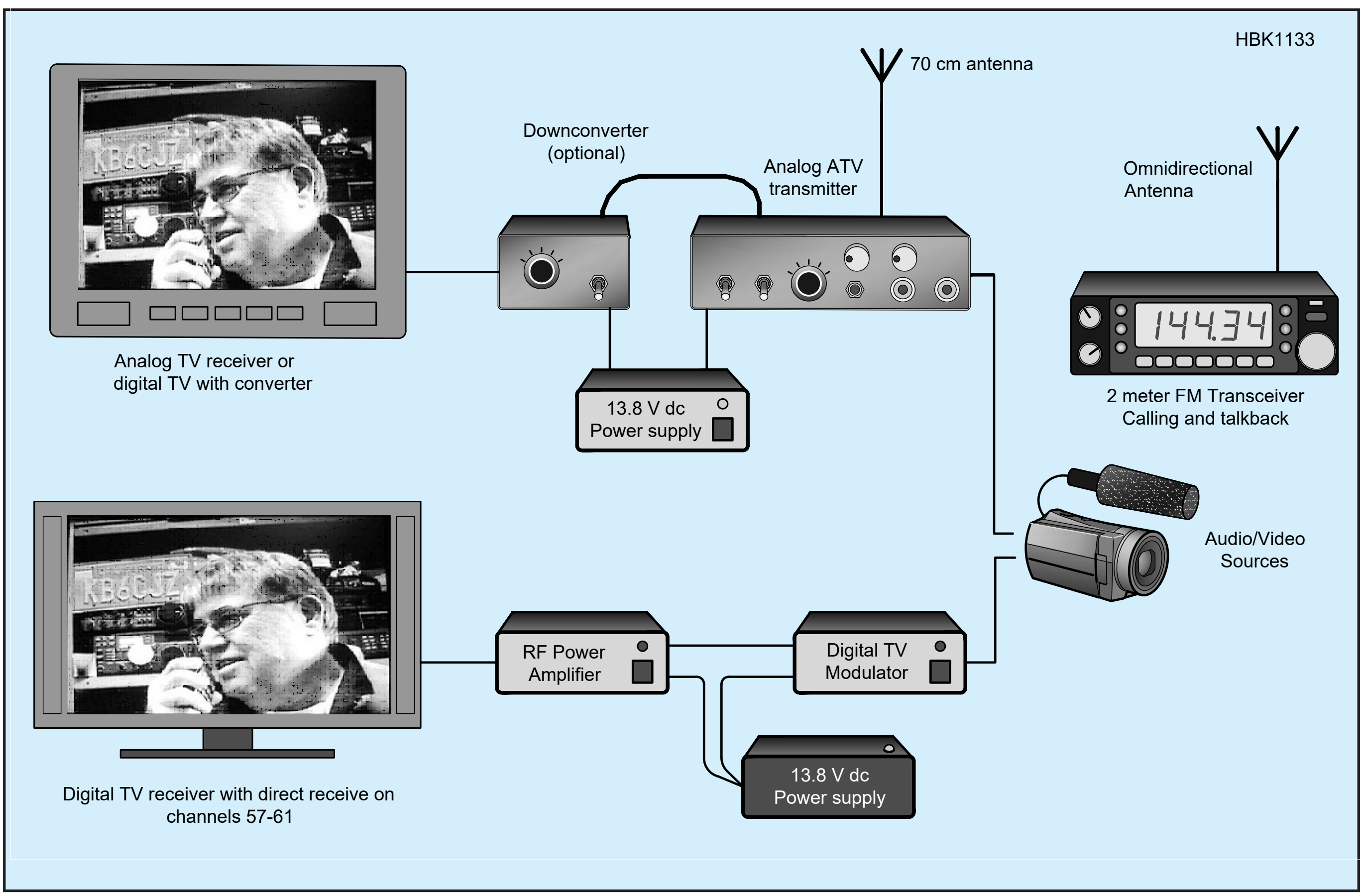


Figure 4 — Block diagram of a basic 70 cm ATV station. See text for equipment requirements. A 2-meter FM channel is often used to coordinate ATV communications.

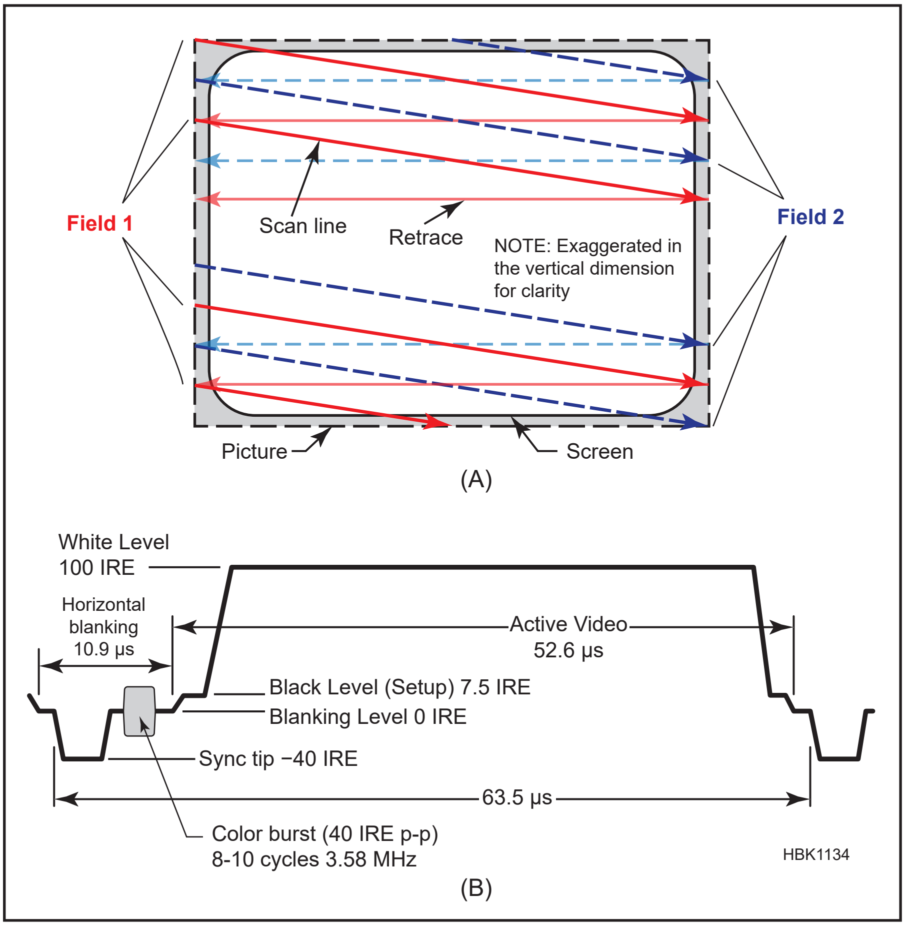


Figure 5 — Structure of an NTSC frame (A) and waveform for one of the horizontal lines. See the Modulation chapter for more details about NTSC video.

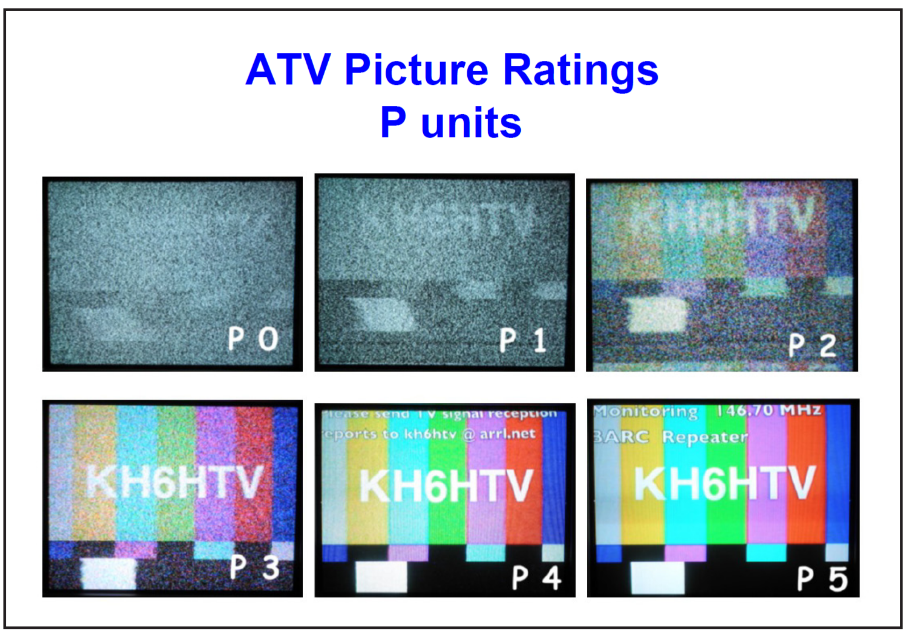


Figure 6 — ATV picture rating system showing images typical of P0 through P5 quality.

width, the original NTSC standards called for filtering out all but 750 kHz of the lower sideband. The result is a Vestigial Sideband (VSB) or Vestigial Upper Sideband (VUSB) signal. The resulting spectrum occupies a 6 MHz-wide TV channel with a 250 kHz guard band. (See the **Modulation** chapter for complete information about analog TV waveforms, modulation, color and audio subcarriers, and the resulting spectrum.)

DSB and VUSB are both compatible with analog cable TV tuners, but the lower sound and color subcarriers are rejected in the TV receiver IF filter as unnecessary. The other significant energy frequencies are the sound (set in the ATV transmitter at 15 dB below the peak sync) and the color at 3.58 MHz (greater than 22 dB down). If the band is full and the lower sideband color and sound subcarrier frequencies need to be used by a dedicated link or repeater, a VSB filter in the antenna feed line can attenuate them another 20 to 30 dB, or the opposite antenna polarization can be used for more efficient packing of the spectrum.

Since the level of intermodulation distortion (IMD) found in most amateur linear amplifiers reinserts the lower sideband to within 10 – 20 dB of DSB, a VUSB filter in the antenna feed line is a sure and cost-effective way to reduce the unnecessary lower sideband subcarrier energy if more than 1 W is used. VSB cable modulators can also be used if strict attention is made to keep the drive level in the proper range of highly linear amplifiers.

Stations operating on non-ATV narrowband modes more than 1 MHz above or below the video carrier rarely experience interference from an AM TV signal, or even know that the transmitter is on the air, unless the narrowband station is operating on one of the subcarrier frequencies or the stations are too near one another.

On the other hand, interference from amateurs who are unaware of the presence of the ATV signal (or in the absence of a technically sound and publicized local band plan) can wipe out the sound or color, or can create diagonal lines in the picture. Because a TV set receives a 6-MHz bandwidth, analog AM TV is more susceptible to interference from many other sources than are narrower bandwidth modes. Many of our UHF (and higher) amateur bands are shared with radar and other government radio positioning services. Signals from these sources show up as horizontal bars or "popping" in the picture.

FM ATV

FM ATV performs far better than AM (or VUSB) TV. A perfect picture can be received at much lower RF power levels with FM. To receive a perfect VUSB TV signal requires a signal-to-noise ratio (SNR) of at least 40 dB and a received RF signal level of about –60 dBm. For FM TV, a SNR of 20 dB results in a perfect, full-quieting picture at a signal level of about -84 dBm. A typical FM TV transmitter uses 4 MHz deviation and a sound sub-carrier in the range of 4.5 to 6.5 MHz.

The typical spectrum of an FM TV transmitter occupies about 15 – 20 MHz. As such, the FM TV spectrum is far too wide for the 70 cm band. There is room on the 33 cm band for only one FM TV channel, typically at 915 MHz.

FM TV is the dominant mode used for analog ATV on the much wider 23 cm and higher frequency microwave bands. C-band satellite receivers and converted Part 15 equipment are occasionally used on the 9 cm (3.3 GHz) and 5 cm (5.6 GHz) bands.

2.2 Digital ATV

For ATV, four modes of digital modulation are currently being used; CATV DTV, ATSC (8-VSB), DVB-S, and DVB-T. The initial DTV modes usually considered by amateurs are ATSC and CATV DTV because they can be received directly on a US home TV receiver. The most popular, with the best performance, are DVB-S and DVB-T, using the European broadcast TV standards. (See the **Modulation** chapter for more information about the various DTV modulations.)

CATV

There are several variations, world-wide, of DTV used for cable TV. In Europe and most of the rest of the world, it is DVB-C. In the US, it is ITU-T_J.83-Annex B. The sole advantage of using cable digital TV is that a 70 cm ATV signal can be received directly on your home TV receiver simply by tuning to cable channels 57 – 61. A stronger RF signal compared to the other DTV modes is required for equivalent picture quality. Early DTV amateurs did experiments with digital cable TV and found it would sometimes work in an over the air broadcast environment, but not reliably. CATV does not tolerate multi-path, which is almost always present for terrestrial broadcasting. It is NOT recommended for ATV use.

ATSC

Advanced Television Systems Committee's (ATSC) 8-VSB system for broadcast DTV is presently the standard used in the US for commercial broadcasts. 8-VSB is an eight-level digital amplitude modulation using vestigial upper sideband filtering. A future version of ATSC 3.0, which was recently approved by the FCC, will not be backwardly compatible with the original ATSC. While US TV receivers receive ATSC, they do not tune the amateur 70 cm band and to use them would require a downconverter. The San Diego, California ATV group is currently experimenting with both ATSC and the new ATSC 3.0.

DVB-S

DVB-S stands for Digital Video Broadcasting-Satellite. It is the DTV standard for satellite TV broadcasting. It was designed to work in an environment with very weak signals and line-of-sight paths from the satellite direct to small Earth dish antennas. DVB-S was not designed for a multi-path environment. DVB-S uses MPEG-2 video compression, forward error correction (FEC) and QPSK modulation. QPSK is the most robust form of DTV modulation as it is a constant amplitude mode, much like FM in this regard. As a result, the transmitter amplifiers can be non-linear, similar to FM.

DVB-T

DVB-T stands for Digital Video Broadcasting-Terrestrial. DVB-T was specifically designed to work in the terrestrial environment of a transmitter broadcasting to home TV receivers where multi-path exists. The terrestrial signal path attenuation can be frequency dependent and can result in a very distorted received signal. The negative effects of multi-path reflections are reduced, by using a modulation with a low effective bit rate per carrier. To reduce the effective bit rate per carrier, DVB-T spreads out the bit rate over a large number of carriers. This spreading out results in either 2,000 or 8,000 closely spaced carriers using COFDM (Coded Orthogonal Frequency Division Multiplexing.)

DVB-T also includes pilot carriers positioned across the channel which are used to correct for channel distortion. A *guard interval* is always included within each COFDM symbol to synchronize the receiver, just as sync pulses are used in NTSC. The guard interval can be adjusted between values of 1⁄32, 1⁄16, 1⁄8 or 1⁄4. A larger guard interval implies a lower bit-rate efficiency and is thus a trade-off between bit rate and network tolerance to echoes and reflections. FEC is also included in the data overhead. FEC values are 1⁄2, 2⁄3, 3⁄4, 5⁄6 or 7⁄8. 1⁄2 means for every real data bit there is also an FEC bit, i.e., 100% overhead. 7⁄8 means for every 7 real data bits there will be one FEC bit. The result is a highly robust system of transmission which corrects for, and eliminates, multi-path in the image. The "ghosting" of the old analog TV transmissions is completely eliminated.

The DVB-T system supports three modulation methods: QPSK, 16-QAM, and 64-QAM. Each quadrant of the QPSK constellation is divided by 16-QAM into four additional sectors, for a total of 16 sectors with three distinct amplitude levels representing different bit values. 16-QAM is thus more susceptible to degradation than QPSK, more like AM vs. FM. 64-QAM divides the 16-QAM constellation sectors into 4 additional sectors, making this modulation even more susceptible to degradation.

2.3 Analog ATV Signal Quality Reporting

For analog ATV a similar method to HF RST signal reports is used to evaluate the quality of the received image. This is the P rating, i.e., Picture rating. **Figure 6** shows examples of various weak analog ATV signals and their respective P ratings.

P0 — Extremely weak signal. At the threshold of the receiver noise. Can only detect the presence of possible sync. No usable image.

P1 — Very weak signal. Can detect presence of video buried in the noise. Mostly snow. Receiver often times has difficulty sync locking. Only very large block letters are barely readable, such as in a camera view of only the call sign on a stationary, automobile license plate. OK for DX reporting only.

P2 — Weak signal. Lots of "snow" present in image. Black and white only. No audio. Can detect presence of people in the image and movement. Not a usable picture for routine, pleasurable viewing. Note: some excellent receivers might show color with a P2 signal in which "snow" is bits of random color called "confetti."

P3 — Moderate signal. Still has snow present in image. Color lock. Audio is present, but noisy. Acceptable picture such as for broadcast TV in very rural areas.

P4 — Strong signal. Very good color and audio. No snow or confetti. Some defects noted in picture quality. Almost full quieting of the FM audio.

P4.5 — Strong signal. Only a very few, minor picture defects. Almost P5.

P5 — Very strong signal. Perfect, noise-free, picture and audio.

It should be noted that most TV receivers now include a *video squelch* circuit and never display a totally noisy screen, but instead switch to a blue screen. The video squelch cannot be disabled on these receivers, preventing a P0, P1, or P2 image from being displayed. Older analog TV receivers and monitors didn't have a video squelch. Thus, if you are interested in doing weak signal analog ATV DXing, it is best to not throw away your old analog TV receiver.

2.4 Performance Comparison of AM, FM, and Digital ATV

Figure 7 is very revealing about the superiority of digital TV versus the older analog AM or FM TV. For AM (VUSB) TV transmissions, to obtain a P5 picture requires an RF SNR >40 dB. For each P unit from P0 to P4, there is an increase in signal strength of 6 dB, i.e., the same definition as used for S units.

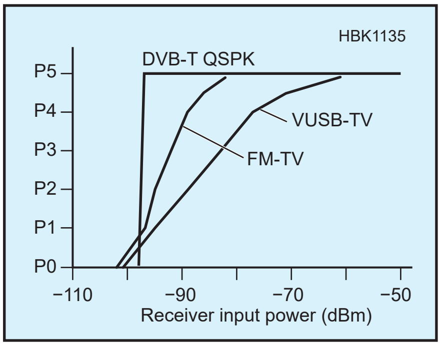


Figure 7 — ATV picture quality versus signal level showing the "digital cliff" of DTV (see text) compared to the more gradual reduction in quality of analog modulations.

For FM TV, the FM quieting effect kicks in earlier and results in a considerably lower SNR required for good to excellent pictures.

For digital ATV, P units are meaningless. With the "cliff effect" in DTV, we either have a perfect picture, i.e., P5, or no picture at all. At the edge of the digital cliff, we might see some "pixelization" (i.e., picture freezing or breaking up in visible blocks) before the picture is lost. This could be considered a P4 picture. The width of the digital cliff is about only 1 dB. Thus, if pixelization is occurring, signal strength is right at the threshold and a drop one more dB will lose the picture completely.

Figure 7 was obtained from measurements using standard 6 MHz NTSC VUSB TV; 4 MHz deviation FM TV; and a DVB-T, QPSK, 6 MHz bandwidth digital signal. For equal RF signal strengths of only –98dBm at the input of a TV receiver, a perfect digital picture results while either of the analog signals are very weak and buried in snow.

Amateurs have run field tests comparing analog vs. digital ATV. The tests were run under identical conditions using the same RF power levels, antennas, locations, etc. Tests comparing either analog VUSB TV or FM TV vs. digital DVB-T (QPSK) resulted in these conclusions:

1. If a P2 analog, VUSB TV picture is received, then in all likelihood, a perfect, P5 digital picture will be received. If the analog picture is P3, a P5 digital picture is guaranteed.
2. Multi-path ghosting was almost always present in the analog picture. No ghosting was present in the digital picture.
3. Mobile operation always resulted in "mobile flutter" on the analog picture, even in strong-signal areas. Mobile reception, even at speeds up to maximum legal speeds of 75 mph, gave perfect digital pictures.
4. For the same RF bandwidth and using digital TV, higher resolution, 1080P vs. 480i pictures were possible.

LATENCY IN DTV

DVB-T digital processing takes time at both ends, which can vary with the type, bandwidth and other parameter modulator settings. The higher the desired picture resolution, the higher the required bandwidth and results in longer latency. Delays can typically be anything from 0.5 to 5 seconds depending on the speed of the codec processors. System latency can be measured by aiming the camera at a clock and taking a photo with a digital camera of the clock and the system video monitor to get the difference in time. It takes some getting used to the wait for another station to respond back to you if running duplex ATV or talking back on 2 meters, especially if using a DTV in/out repeater where the latency will be double that of simplex. It also takes time for the DVB-T receiver to sync up and lock on to the new signal after another station starts transmitting. These delays can vary from tenths of a second to many seconds. Thus, for safety reasons, DTV should not be used for piloting R/C aircraft.

Delays make it more difficult to aim and focus the cameras if monitoring your own video. Camcorders are preferred for DTV as they have a real time monitor built in and most current ones have the HDMI output for direct connection to monitors and DVB-T modulators. Controlling an R/C vehicle can be more challenging with DATV vs. AM or FM ATV because of latency.

2.5 Station Identification on ATV

For ATV, the FCC accepts either a visual or audio ID. From your home station, this can be as simple as holding a QSL card in front of the camera and/or making a voice announcement. An analog ATV repeater usually superimposes the repeater's call sign on the video and/or with a Morse code ID superimposed on the audio.

Digital ATV automatically identifies the signal with every frame of video. Included in the digital data stream is a header of meta-data describing for the receivers, the modulation parameters used, including the call sign of the transmitter. This satisfies the FCC's requirement to ID. However, to be on the safe side, most DTV repeaters also actually switch a separate video ID source with the station call letters into the video stream every 10 minutes.

3 Amateur TV Signals

3.1 ATV Frequencies

ATV transmissions require a 6 MHz wide channel which is wider than all amateur HF bands combined. We have to move up to the UHF region before we find enough bandwidth available to support TV signals. The lowest frequency amateur band available for ATV is the 70 cm band (420-450 MHz). It is 30 MHz wide and could support up to five 6 MHz, TV channels (see **Figure 8**). Note the channel numbers 57 through 61 in Figure 6. US cable TV uses all of the spectrum from 54 MHz (Ch. 2) up to about 1 GHz, divided into adjacent 6 MHz channels. It turns out that CATV channels 57 through 61 are actually in the amateur 70 cm band. This is fortunate, in that a 70 cm AM ATV transmitter's signal can be received directly on an analog TV receiver.

The 70 cm band is by far the most popular of all the amateur bands for ATV. It has the combination of good propagation characteristics, the most available equipment, reasonable size antennas, etc. The ARRL band plan for 70 cm calls for Channel 58 to be used for simplex ATV while Channel 60 and Channel 57 are to be used as the input and output channels for an ATV repeater. The use of the other channels for TV is not recommended due to likely RFI to FM voice repeaters on Channel 61 and weak signal SSB/CW and satellite signals on Channel 59. It should be noted that not all regions of the US adhere to the ARRL band plan for ATV. Some regions use non-standard frequencies. The most common being 426.25 MHz and 434 MHz for analog ATV. If an ATV repeater (see below) is operating, simplex ATV operation takes place on the repeater input channel.

Simplex, public service, and R/C models use 426.25 or 427.25 MHz in areas with cross-band repeaters, or as an alternative to the main ATV activities on 434.0 or 439.25 MHz. The spectrum power density is so low at frequencies greater than 1 MHz from the video carrier of an AM analog ATV transmission that interference potential to other modes is low. In the more populated areas, 2 meter calling or coordination frequencies are often used to work out operating time shifts or other techniques to accommodate all users sharing or overlapping the same segment of the band.

All of the higher frequency amateur bands can also be used for ATV. As one goes higher in frequency, these microwave bands become more useful for point-to-point TV links, rather than wide-area TV broadcasting. The next most popular band after 70 cm is the 23 cm band (1240 – 1300 MHz). With 60 MHz available, it could support up to ten, 6 MHz TV channels. In most areas, it is a fairly quiet band with much fewer users. The main issue for some large metro areas is the presence of government radars within the 23 cm band as the primary service in this band. As a secondary service, amateurs are not allowed to interfere with these radars.

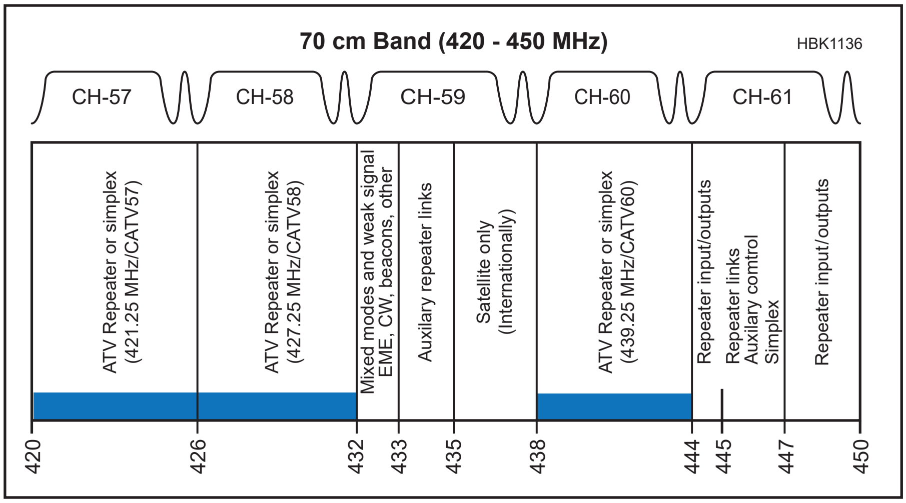


Figure 8 — 70 cm band plan showing video channels for cable TV and other amateur activities.

Above 23 cm, the 33 cm (902 – 928 MHz) and the 13 cm (2.39 – 2.45 GHz) bands are considerably less useful due to the shared usage with unlicensed, Part 15 devices. The 2.4 GHz band is especially difficult because of its widespread use for WiFi. There is also some ATV activity in the higher microwave bands at 9 cm (3.3 – 3.5 GHz), 5 cm (5.65 – 5.925 GHz) and 3 cm (10 – 10.5 GHz). ARRL band plans exist for all of these various bands and specific channels have been set aside for ATV use.

3.2 ATV Propagation

One of the first questions prospective ATVers ask is "How far will my TV signal go?" The best answer is "line of sight." Comparing a TV signal with an FM or SSB voice signal, using the same power levels, antennas, etc., the TV signal will not go nearly as far as the narrow-band voice signal. This is set by the fundamental laws of physics. The limit is set by the noise floor of the receiver, which is a function of bandwidth. The thermal noise floor power is given by the equation:

$$P_n = k \times T \times BW$$

where k is Boltzmann's constant (1.38×10^{-23}), T is absolute temperature (290 K), and BW is the bandwidth (in Hz). The amount of thermal noise power in a 1 Hz bandwidth is thus –174 dBm. For various typical receiver bandwidths, the noise floor power is: –147 dBm (500 Hz, CW), –140 dBm (2.4 kHz, SSB), –132 dBm (15 kHz, FM voice), and –106 dBm (6 MHz, TV). Any additional noise in the receiver, as measured by its noise figure will further raise this noise floor. Thus, for TV we take an extra penalty of more than 20 dB over the performance of an FM voice signal. (See the **RF Techniques** chapter for more information about noise, noise factor, etc.)

For line of sight, UHF, and microwave propagation, the question of "Where is the radio horizon?" also matters. If we lived on a flat earth, the answer would be infinity. Because we live on a spherical earth (radius = 6,370 kilometers), the curvature of the earth limits our horizon. It effectively puts a "hump" in the middle of our RF path. The radio horizon is actually a bit further distant than the geometrical horizon. (See the **Propagation** chapter for more about atmospheric propagation and the radio horizon.) The refractive effects of the atmosphere cause a bit of bending in the radio waves and will allow them to propagate about 15% further so that the radio horizon distance is:

$$\text{RF distance (miles)} \approx 1.41\sqrt{\text{height (ft)}}$$

Atmospheric effects are totally dependent upon local weather conditions. In extreme cases, strong ducting might occur sending our RF waves far beyond the predicted RF horizon, while severe local storms might reduce it dramatically.

A few examples of radio horizons calculated from antenna height are: 5 feet ~3.2 miles, 30 feet ~7.7 miles, and 100 feet ~14 miles. To account for antenna height at the receive site, add the horizon distances together. For example, transmitting from an automobile with an antenna height of 5 feet to a remote base station with the antenna on a 30-foot tower, the radio horizon = 3.2 + 7.7 ≈ 11 miles. This calculation really only works over flat earth, not hilly or rolling terrain. On a large lake or the ocean, we do have such a flat surface. Obviously either putting up a higher tower or finding a high hill or mountain top works wonders.

After determining the radio horizon, the next issue to contend with is RF path loss. Due to spherical geometry, the transmitted RF gets spread equally over an ever-expanding sphere as it propagates away from the source. Thus, the power density in watts/m^2 gets smaller the further we get from the source. The formula for free space path loss based solely upon this geometry is:

$$\text{Free Space RF Path Loss (dB)} = 20\log_{10}(\text{f in MHz}) + 20\log_{10}(\text{D in miles}) + 36.6\text{ dB}$$

Note the frequency dependency in this equation. For example, going from 70 cm to 23 cm we suffer about a 10 dB increase in path loss. The equation assumes the use of a ¼-wave antenna. The frequency dependency is because the effective area of a ¼-wave antenna is a function of wavelength. The shorter the wavelength, the smaller the effective area to capture an RF wave. As an example, for the 70 cm band (430 MHz): 0.1 mile = 69 dB, 1 mile = 89 dB, 10 miles = 109 dB, etc.

We can also calculate the distance for a given path loss:

$$\text{D in miles} = \log_{10}^{-1}\left(\left(\text{Path Loss (dB)} - 20\log_{10}(\text{f in MHz}) - 36.6\text{ dB}\right) / 20\right)$$

Where $\log_{10}^{-1}$ (X) is the inverse logarithm of X which can also be computed as 10^X.

To determine the best-case situation for a particular RF path we need to include all of the major RF components. Calculations are done easiest in dB with power levels expressed in dBm and antenna gains expressed in dBi. To determine the power input into the distant receiver, we need to know the transmit power, cable loss of both stations, antenna gain of both stations, and the path loss:

Rcvr Pwr (dBm) = Trans Pwr (dBm) – Trans Cable Loss (dB) + Trans Ant Gain (dBi) – RF Path Loss (dB) + Rcvr Ant Gain (dBi) – Rcvr Cable Loss (dB)

Solving to find the maximum path loss for that combination of receiver input power, transmit output power, antenna gain, and cable loss:

RF Path Loss (dB) = Trans Pwr (dBm) – Trans Cable Loss (dB) + Trans Ant Gain (dBi) – Rcvr Pwr (dB) + Rcvr Ant Gain (dBi) – Rcvr Cable Loss (dB)

We convert the path loss to free-space line-of-sight distance in miles using the equation above.

As an example, using the parameters of a typical 70 cm analog TV station, what is the maximum line-of-sight distance at which a P5 picture can be received? That requires Receiver Power = -65 dBm (40 dB SNR, P5 for analog VUSB TV). Start by finding the maximum allowed path loss:

Transmitter Power = 5 watts (+37 dBm),
Cable Loss = 1 dB each end, and
Yagi Antenna Gain = 11 dBi at each end

RF Path Loss (dB) = 37 dBm – 1 dB + 11 dBi – (–65 dBm) + 11 dBi – 1 dB = 122 dB

Finally, convert that path loss to a distance in miles:

D in miles = $\log_{10}^{-1}$ ((122 – 20 $\log_{10}$ (420) – 36.6) / 20) = 44 miles

For this station, a 44-mile, unobstructed, free space, line of sight path is the farthest distance at which a P5 quality signal can be received. These theoretical results really only apply for outer space applications. In the real, terrestrial world, we encounter a lot of other obstacles and we would never achieve this ideal. In practice, direct line-of-sight ATV contacts seldom exceed 25 miles.

In 2011 and again in 2016, several Boulder, Colorado area TV hams have run TV propagation field trials. Measurements were taken of the actual received signal strength in dBm. One observation that stood out was "Over very clear, line-of-sight paths, even with directional antennas, where multi-path was not a major issue, the actual path loss was typically 5 to 15 dB worse than the calculated, theoretical path loss." For obstructed paths, even more loss was typically encountered. Thus, the likelihood of our ever experiencing just free space path loss is extremely rare.

The above equations were for ideal, unobstructed, line of sight situations. What limits us in the real world? Lots of things, such as ground reflections, vegetation, tall buildings, urban building clutter, hills, ridge lines, mountains, etc. The absorption by vegetation, due to water content, goes up with increasing frequency. Getting over obstructions to our line-of-sight path involves diffraction which can introduce considerable extra loss.

Most of the other remaining losses result from multi-path. This is reflected waves from other objects which arrive at the receive site later in time and might totally cancel the desired direct path signal. Another perturbing effect is Doppler shift due to moving objects disturbing the various multi-paths.

A pure, free space, channel is called "Gaussian." It is very rare in a terrestrial environment. If there is a direct line-of-sight path, but also multi-path signals arriving at the receive antenna, then this is called a "Ricean" channel. If there is no direct line-of-sight path, but multi-path signals arrive at the receive antenna, this is then called a "Rayleigh" channel. Each type progressively degrades the channel performance and leads to more path loss.

3.3 Propagation Prediction

Radio Mobile is an excellent free, online, computer program for calculating RF propagation in actual terrain. (**www.ve2dbe.com/english1.html**). This program was written and copyrighted by Rodger Coudé, VE2DBE. The free, online version is dedicated to amateur radio use and as such will only accept input frequencies in the amateur radio bands. The mathematical model is a mix of the Longley-Rice model, the two-rays method, and the land cover path loss estimation. *Radio Mobile* first calculates the free-space path loss. It then adds estimates for the excess path loss contributions from: Obstruction Loss, Forest Loss, Urban Loss, and Statistical Loss (typically always set to about 6.5dB). *Radio Mobile* uses topographical information from Google Earth maps. *Radio Mobile* can calculate point-to-point RF path profiles and also wide area RF coverage maps. Comparing *Radio Mobile's* point-to-point predictions with the results from actual, mobile, field measurements of ATV signals demonstrates good agreement. (See AN-33a on KH6HTV's website, **www.kh6htv.com.**) The ATV repeater coverage maps (see below) also correlate well with the field measurements.

While *Radio Mobile* is good for normal propagation conditions, ATV hams have taken advantage of exceptional atmospheric conditions to set world long distance DX-TV records. Perhaps the longest was set in 1994 by KC6CCC in San Clemente, California when he received an ATV beacon test pattern from KH6HME in Hawaii during a tropo opening. It was on the 70 cm band and the distance was 2,518 miles. The ATV hams in the eastern US routinely experience tropo openings exchanging ATV signals over 200 – 300 miles. To predict when tropospheric propagation is possible, hams use the Hepburn Tropo Ducting Forecast at **www.dxinfocentre.com/tropo_wam.html**, especially in the summer months.

Receiving a strong, 2-meter, FM voice signal from an ATVer or ATV repeater provides a strong initial indication that a local path is open. Some ATV repeater web sites have a coverage map you can check to see what the expected signal strength is for your location — see **www.atn-tv.com/repeaters/coverage-maps**.

4 ATV Repeaters

ATV repeaters are typically on the 70- or 23-cm bands and there are also some ATV repeaters on the microwave bands. Most of the ATV repeaters are still for analog TV, but some are now transitioning to digital TV. Repeaters can be linked by microwave or as networked video over the internet. The Amateur Television Network (ATN) (**www.atn-tv.com**) is a linked ATV repeater system tying together seven southern California, one Nevada, and three Arizona ATV repeaters.

The ultimate ATV repeater is the geostationary, QO-100 amateur satellite. It is a DVB-S repeater with its uplink on the 2.4 GHz band and downlink on the 10 GHz band. However, its footprint only covers Europe, Asia and Africa, not the western hemisphere.

> **TV Repeater Streaming**
>
> If you would like to see what other ATV groups are doing, it is now a simple matter to watch their video over the internet. The British Amateur TV Club (BATC) now offers an internet video streaming service from their server in the UK. You do not need to be a member of the BATC to watch. On their web site at **batc.org.uk**, click on "Streamer". A/V streaming is available there from members and also member TV repeaters. You will find video there from ATV hams all around the world, primarily from the UK but also other countries, including the US.

4.1 In-Band ATV Repeaters

Most FM voice repeaters can use a single antenna for receive and transmit. This requires the use of a duplexer to separate the signals and isolate the transmitter from the receiver. For TV signals with bandwidths of 6 MHz, the ratio of transmit/receive separation to bandwidth on the 70-cm band is only 18 MHz / 6 MHz = 3:1. It is very difficult to build a duplexer which can provide sufficient isolation for such a condition. Thus, ATV repeaters typically use separate antennas for receive and transmit. Isolation is achieved by separation of the antennas. The best arrangement is for the antennas to be mounted vertically on a common axis. As an example, for two 70 cm, vertically polarized antennas mounted vertically on the same common axis and separated by 10 ft, the isolation is 54 dB. To achieve the same isolation if they are instead separated horizontally from each other, would require a separation of at least 100 feet. For cross-band repeaters, additional isolation is provided by the frequency selectivity of the antennas.

A basic, single-band analog ATV repeater usually consists of two antennas, one for receive and the other for transmit. A pair of very sharp cut-off bandpass channel filters are required on both the receiver and transmitter to provide the required isolation to keep the transmitter's signal out of the receiver. The audio and video outputs from the TV receiver are then fed into the TV transmitter. There also needs to be a circuit to detect the presence of an incoming ATV signal. **Figure 9A** shows a basic analog ATV repeater block diagram.

Analog TV repeaters use a form of tone squelch called *video-operated relay* (VOR) for recognizing an incoming TV signal to key the repeater. Instead of the typical sub-audible tone, VOR detects the presence of the 15 kHz horizontal sync pulse. Video ID can be added to the relayed signals with a video overlay board like the Intuitive Circuits model OSD-ID+ or even overlaid on a tower cam. Call sign characters and other information can be programmed into nonvolatile memory. Some overlay boards will also accept NMEA-0183 standard GPS data.

The repeater transmitter power supply should be separate from the supply for the rest of the equipment. With AM ATV the current varies greatly from maximum at the sync tip to minimum during white portions of the picture. Power supplies are not generally made to hold tight regulation with such great current changes at rates up to several megahertz. Even the power supply leads become significant inductors at video frequencies. They will develop a voltage across them that can be transferred to other modules on the same power supply line.

The most popular in-band repeater output frequency is 421.25 MHz and is the same as cable channel 57. At least 12 MHz of separation is necessary for in-band repeaters because of TV set adjacent-channel rejection and VUSB filter characteristics.

4.2 Cross-Band ATV Repeaters

Cross-band ATV repeaters free up a channel on 70 cm for simplex operation and make it easier for repeater users to monitor their own repeated video with only proper antenna

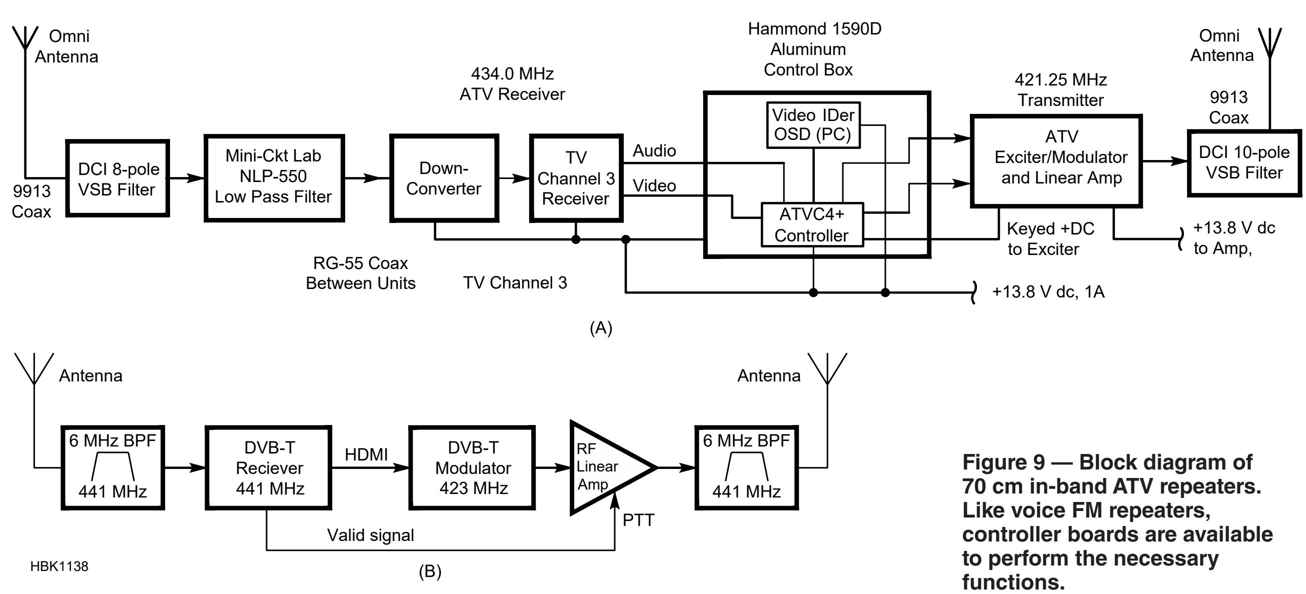


Figure 9 — Block diagram of 70 cm in-band ATV repeaters. Like voice FM repeaters, controller boards are available to perform the necessary functions.

separation needed to prevent receiver desensitization.

A basic cross-band repeater for DVB-T ATV is surprisingly easy to assemble. **Figure 9B** shows the basic elements. It is far easier to build than a typical FM voice repeater or an older NTSC analog TV repeater. The basic elements required are just the DVB-T receiver, the DVB-T modulator and an RF linear power amplifier, plus the appropriate antennas. However, if any other features are added to the repeater, such as multiple receivers, dual-mode, extra video sources, etc., then it becomes a very complex engineering project quickly. A cross-band repeater requires less sophisticated filtering to isolate the transmitter and receiver because of the great frequency separation between the input and output. No duplexer is needed, only sufficient antenna spacing or low pass and/or high pass filters. In addition, a cross-band repeater makes it easier for users to see their own video. Repeater linking is easier too, if the repeater outputs alternate between the 23- and 33-cm bands.

For an in-band DTV repeater, bandpass filters are also required on the input and output. These filters need to be wide-band to match the channel bandwidth, usually, 6 MHz. They also need to be low-loss and have very steep skirts. Most TV repeaters use inter-digital BPFs.

Notice that the interconnection in Figure 9 consists simply of an HDMI cable between the receiver and modulator, coax cables for the RF circuits, and a single control signal, called "Valid Signal," from the receiver to the power amplifier to act as a PTT signal. If this is a local, manually controlled repeater, set up temporarily, this signal is not needed, just the control operator operating the power amplifier's power switch. For automatic repeater operation, we do need the "Valid Signal" control signal.

Most DVB-T receivers include an LED indicator showing when the receiver is receiving a valid DVB-T signal. The LED typically goes from red to green when a valid signal is received. The drive signal for this LED can be buffered with a simple transistor circuit to provide an open collector to ground logic output. This is then connected to the PTT input on the RF linear power amplifier.

4.3 Narrow Bandwidth DTV Repeaters

In the US, analog ATV repeaters using VUSB TV are constrained to using 6 MHz channels. Modern, digital ATV repeaters are not restricted to 6 MHz channels. In major metropolitan areas, such as Los Angeles, the 70-cm band is crowded, and it is difficult to find available spectrum for a 6 MHz channel. Fortunately, in response to requests from the ATV community, Hi-Des (see the next section) has modified their DVB-T equipment to allow it to also work with narrower bandwidths than the world-wide commercial broadcast 6, 7, or 8 MHz channels. Their equipment will work with bandwidths as narrow as 1 or 2 MHz. The Amateur Television Network (ATN) in southern California is successfully using 2 MHz wide DVB-T channels for their DTV transmitters. Using 2 MHz-wide 16-QAM, they are successfully transmitting hi-definition, 720P video. DTV repeaters elsewhere are also successfully operating in a 4 MHz channel.

5 Equipment for ATV

5.1 TV Video Sources

The very first acquisition required if one is interested in getting on the air with ATV should be a TV camera: the author recommends an inexpensive video camcorder. Very good, high definition (1080P), digital camcorders are now available new in the $200 – $300 price range. They include a zoom lens, built-in stereo microphones, built-in monitor screen, SD card memory, and battery/ac operation. Their audio/video (A/V) output is via an HDMI interface. (HDMI is the common digital A/V cable found on all modern consumer video products.) There is also a USB port for transferring video to a computer.

Some, but not all of the current production camcorders include analog, composite (480i) video plus stereo line level audio output. Inexpensive ($10 – $20) HDMI to Composite Video-plus-stereo audio adapters are available if you also need composite analog video and audio. With the built-in memory in a camcorder, you can record events and then play them back later through the ATV transmitter.

Most modern digital cameras, including smartphones, also include video recording ability. You need to shop very carefully if these will be your ATV camera. Questions to ask about the cameras include:

1. Will the camera output both video and audio on the HDMI cable in the stand-by mode? Some only output video.

2. Will it output both video and audio while recording? Some cameras only output A/V during playback.

3. Is the resolution at the A/V port the same as the camera recording? Some record in high-definition, but only output standard definition.

4. Can the time-out function be disabled to prevent unintended automatic shut off?

5. Does the camera autofocus in the movie mode? You need to be able to zoom the lens without manual focusing.

Ask lots of questions of the salesclerk or online sales assistance and ask for actual demos before purchasing.

Other sources of video include security cameras, VCRs, DVD players, and your home PC computer. Older, analog, TV cameras with composite video and audio output are available at very low cost, as well. Most computers provide an output for an external monitor, plus a line level audio output. On older computers, the monitor output was in the VGA format. Newer computers provide monitor output using the HDMI format. Again, if you need a different video format, inexpensive converters can be found readily on the internet.

A PC can also be the single video source if equipped with a built-in camera and microphone. This allows you to combine a live image and voice with other material on your computer to present a multi-media production for your fellow ATV hams to watch.

5.2 Equipment for AM Television

AM TV RECEIVERS

Analog AM TV remains the most popular modulation method used for ATV. Since the 70 cm band corresponds to cable TV channels 57 through 61, seeing your first ATV picture may be as simple as connecting a good outside 70 cm antenna (aligned for the customary local polarization) to a cable-ready TV set's antenna input jack. Your broadcast TV antenna, twin-lead or RG-6 coax may not be good enough for receiving the much lower power ATV transmissions. Cable channel 57 is 421.25 MHz, and each channel is progressively 6 MHz higher. Cable-ready TVs may not be as sensitive as a low-noise downconverter designed just for ATV, but this low-cost technique is well worth a try. A higher gain antenna and/or low-noise antenna preamp, preferably at the antenna, can be added later if the picture has snow in it.

It is also possible to use a variable tuned or crystal referenced downconverter specifically designed to convert the whole amateur band down to a VHF TV channel. Generally, the 70- and 33-cm bands are converted to TV channel 3 or 4, both rarely used for broadcast today. For 23 cm converters, channels 7 through 10 are used to get more mixer image rejection.

The downconverter consists of a low-noise preamp, mixer and tunable or crystal-referenced local oscillator. Any RF at the input comes out at the lower frequencies. All signal processing of the AM video and FM sound is done in the TV set. A complete receiver with video and audio output would require all of the TV set's circuitry except the sweep and video display components. There is no picture quality gain by going directly from a receiver to a video monitor (as compared with a TV set) because IF and detector bandwidth are still the limiting factors. Automatic Frequency Control (AFC) in a TV will normally lock on to a video carrier over a little more than ±1 MHz, so frequency drift and accuracy are not nearly as significant as experienced with voice modes. For instance, a TV set to cable channel 59 (433.25 MHz) will normally lock on to a 434.0 MHz ATV signal. A good low-noise amateur downconverter with 15 dB gain ahead of a TV set will give sensitivity close to the noise floor. A preamp located in the shack will not significantly increase sensitivity, but rather may reduce dynamic range and increase the probability of intermodulation interference. Sensitivity can best be increased by reducing feed line loss or increasing antenna gain. Or you can add an antenna-mounted preamp, which will eliminate the effects of loss in the feed line and loss through TR relays in the transmit linear amplifier. Each 6 dB total improvement — usually a combination of increased transmitter power, antenna gain or receiver sensitivity and reduced feed line loss — can double the line-of-sight distance or improve quality by 1 P unit (a measure of picture quality).

The cost of an AM ATV transmitter is relatively low. If using the 70-cm band, a home TV receiver will receive 70 cm, NTSC, AM TV, or VUSB TV signals directly. Simply set the TV to the cable TV mode, attach an antenna instead of to the cable system, and tune to channels 57 through 60 for ATV activity. (See the previous section on signal quality regarding video squelch in new televisions.)

Another solution is an analog TV demodulator. These were used by the cable companies at their head ends and by hotels for in-house video distribution systems. You still might need a monitor which doesn't include video squelch.

AM TV TRANSMITTERS

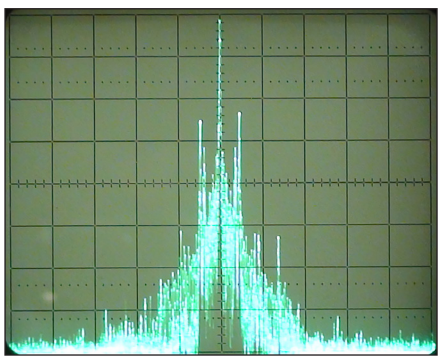
AM TV transmitters previously available from PC Electronics (**www.hamtv.com**) which is no longer in business but these transmitters are still available on the used equipment market. The website is still active as of 2022 and has a lot of information about this equipment.

Essentially the only 70 cm, AM TV transmitter commercially available new in 2022 is the VideoLynx designed by Ravi, KA3NNJ, and sold by MFJ Enterprises. (**mfjenterprises.com**) There are two models available, frequency synthesized with four channels, and with RF output power ranging from 50 mW to 5 Watts (the higher power unit requires a heat sink). The 50-mW unit is suitable for use as a modulator driving a higher-power amplifier. It is also suitable for use with radio controlled (R/C) aircraft. The standard units come with two of the channels programmed with standard CATV channels, i.e., 427.25 MHz (Ch 58) and 439.25 MHz (Ch 60). The other two are non-standard; 426.25 MHz and 434 MHz. For the equipment to work on channels 57 and 59, contact MFJ.

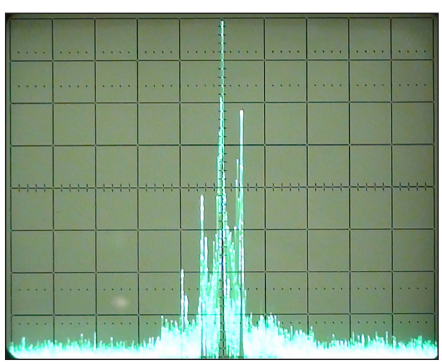
AM TV is discouraged today for the reason of spectrum conservation. A typical ATV, AM TV transmitter has a very broad spectrum beyond the 6 MHz wide channel required as shown in **Figure 10A**. To be a good neighbor and not use excessive spectrum, hams are encouraged to convert their AM TV transmitters to 6 MHz wide VUSB TV.

VUSB TV

It is possible to adhere to the 6 MHz bandwidth limits using VUSB. Simply adding a 6 MHz wide, bandpass filter with steep skirts to the output of an AM TV transmitter will accomplish this. Unfortunately, there are not many suppliers of such filters and they are expensive. Another approach is to use cable TV analog modulators. These create a VUSB TV signal at the 1 mW (0 dBm) level and then amplify it with a linear RF power amplifier. Figure 10B shows the spectrum of a VUSB TV signal. Its spectrum is much cleaner compared to the AM TV transmitter in Figure 10A. CATV modulators such as the Blonder Tongue MDDM 860 (**www.blondertongue.com**) are still available new and surplus at relatively low prices.



(A)



(B)

Figure 10 — Typical spectrum of AM TV (A) showing the broad, double-sideband signal. VUSB TV is shown in (B) occupying less spectrum and near-broadcast quality. (Vertical axis is 10 dB/div and horizontal axis is 10 MHz/div.)

If you are using the modulator plus amplifier arrangement, take care to not overdrive the amplifier. With ATV, driving your amplifier to get the most RF power indicated on a power meter will distort the TV signal and make it unreceivable. With AM TV, overdriving the amplifier will clip the sync pulses and severely compress them. This will make it harder for viewer's TV receivers to lock onto the signal. Older PC Electronics AM TV transmitters have a built-in "sync stretcher" circuit that allowed users to drive their amplifiers for maximum output power on the sync tips. Details on how to adjust these transmitters was included in the instruction manual. If you are using a CATV modulator you will not be able to stretch the sync pulses, so amplifier drive needs to be carefully monitored.

5.3 Equipment for FM Television

With the transition to DTV, most commercial grade FM TV equipment has disappeared from the market. The main exception now are inexpensive transmitter/receiver pairs intended for use in the drone to give the drone pilot a live view from the aircraft. Packages are available for the Part 15, unlicensed 900 MHz, 2.4 GHz and 5.8 GHz bands.

Be wary of products being marketed for the 1200 MHz region and for "Ham" use. The ARRL and FCC have been clamping down on these because they also transmit illegally on frequencies outside of the amateur 23 cm band. Specifications for these are limited or non-existent and RF power output specifications are typically overly optimistic.

As of 2022 the most readily available equipment is for the 5.8 GHz band and available online. A complete 5.8 GHz, 600 mW, FM TV transmitter and receiver pair such as the AKK RC832/TS832 pair (**www.akktek.com**) can be purchased for about $30. Both are frequency synthesized with 40 channels. To use this equipment, only an analog TV camera needs to be added to the transmitter and a video monitor to the receiver.

C-band satellite TV receivers directly tune anywhere from 900 to 2150 MHz and may need a preamp added at the antenna for use on the 33- and 23-cm amateur bands. Early satellite TV receivers were made for antenna mounted LNBs (low noise block converters) with 40 dB or more gain. Satellite receivers are made for wider deviation (11 MHz) and need some video gain to give the standard 1-$V_{P\text{-}P}$ video output when receiving a signal with standard 4-MHz deviation. The additional video gain can often be had by adjusting an internal control or changing the gain with a resistor.

5.4 Equipment for Digital Television

The most popular DTV mode in the US is currently DVB-T. DVB-S is more popular in Europe for DTV. For more information about DVB-S and available equipment, see the British Amateur Television Club (BATC) web site: **www.batc.org.uk**.

5.4.1 DVB-T RECEIVERS

For any of the DTV modes except ATSC, a standalone receiver is required which uses a television monitor to display the resulting audio and video. For digital TV, use the HDMI cable connection. Standalone ATV receivers function in the same fashion as the set-top boxes supplied by many cable companies and satellite dish companies.

Inexpensive DVB-T set-top boxes designed for the European consumer market are readily available online. They work with bandwidths of 6, 7 and 8 MHz. However, many of them will not tune the amateur 70 cm band directly, even though their specifications cover from 174 to 850 MHz. Hi-Des in Taiwan does make set-top receivers such as the HV-110 and HV-122 (**www.hides.com.tw**) which cover all frequencies from 50 MHz to 2.5 GHz, including the 2 m, 70-, 33-, 23-, and 13-cm bands and work with bandwidths from 1 to 8 MHz.

Most modern TV receivers do not allow us the ability of random access from our remote control to any arbitrary TV channel the way we used to do it with analog NTSC TV. Typically, the receiver must search every TV channel (called "channel scan") to locate another DTV signal. This can make it difficult to train a TV receiver to receive an amateur DTV signal. If you have your own DTV modulator, you can set it for each channel to be used and then train your own receiver. If you are just a DTV viewer, you can take your receiver to another local DTV station to train your receiver from that modulator's signal.

Another option for DVB-T is to purchase an inexpensive TV tuner in a USB "dongle" for your personal computer. Most of these are based on an R820T DTV tuner IC and an RTL2832U DVB-T COFDM demodulator IC with a USB interface. The tuner's frequency range is specified to be 42 to 1002 MHz with a 3.5 dB noise figure. (These receivers are also discussed in the **Transceiver Design Topics** chapter.) While this is a very inexpensive approach, it is not a simple turn-key solution such as a set-top receiver. A PC and some computer skills are required to use this approach. The general-purpose video processing software *VLC* (**www.videolan.org**) works well with these tuners. *VLC* is a free, open-source, cross-platform multimedia player software. Successful use of *VLC* depends upon the version of Windows and having the correct driver.

VLC allows tuning to any arbitrary frequency direct from the PC without requiring channel scanning. Receiver sensitivity tests were performed on several different brands of these receivers with the best minimum detectable signal at –93 dBm and the worst at –72 dBm (tested on 6 MHz bandwidth QPSK, DVB-T).

5.4.2 DVB-T MODULATORS

The Taiwanese company, Hi-Des referenced previously offers a line of affordable modulators and receivers for the digital signage, in-house video distribution, FPV, and amateur TV markets. Their equipment is frequency synthesized and offers continuous coverage from 100 MHz up to 2.5 GHz in some units. This equipment is very simple to operate.

The modulator does require a minimal amount of initial setup, mainly to program it with the desired TV channel(s). Other parameters, such as Forward Error Correction (FEC) can also be adjusted. A windows program called *AV-Sender* is supplied for this purpose and connects to the modulator via a USB cable. After programming, an external PC is no longer required.

A PC is not required for the Hi-Des receiver. It is programmed using the supplied remote control. Most DVB-T equipment supports bandwidths of 6, 7, and 8 MHz, i.e., commercial broadcast standards. In response to requests from ATV users, Hi-Des equipment such as the HV-320E shown in **Figure 11** supports narrower bandwidths from 1 to 8 MHz. Hi-Des also offers customer support via e-mail.

5.5 Portable ATV Equipment

5.5.1 ATV GO-KITS

Communications go-kits are popular with ARES and RACES groups. When an emergency occurs, hams can just grab their kit and go out in the field with everything they need. A kit should be constructed in an easy-to-transport enclosure with wheels and a handle. The ATV transmitter, 2-meter transceiver, battery, and an optional video monitor can be fastened directly to the enclosure or to a plywood base cut to fit the inside of the enclosure. A dc power supply can also be added if ac is available, or power can come from a dc extension cord with clips to connect to a car battery.

If the distance to be covered is short enough, a 2-meter/70-cm dual-band mobile vertical antenna connected through a duplexer and mounted on at least 10 feet of TV mast above the go-kit is sufficient for communication with a mobile command post. Longer or obstructed paths between the incident site and the EOC may require beams and more antenna placement care.

Multiple ATV go-kits allow for views of an incident site from different perspectives, including the police department helicopter and mobile or portable stations on the ground. The go-kits can also be used for parades, running and bike races, which are good operational practice for when the real emergency might happen.

Figure 11 — The author's ATV transmitter system consists of a Hi-Des HV-320E DVB-T modulator driving a KH6HTV 70-7B linear amplifier for the 70 cm band. The modulator also tunes the 33, 23, and 13 cm bands and has an adjustable output up to 6.5 dBm on 70 cm.

5.5.2 PORTABLE ATV REPEATERS

A portable ATV repeater for public service events can also be built in a portable enclosure or a milk crate for easy transport and set up on the top of a building or hilltop by car or even helicopter. The path between an ATV station in the field and the EOC is rarely line-of-sight, so the portable ATV repeater can be placed at a high point that can be accessed from both locations.

A cross-band portable repeater can use a 70 cm input and 23 cm output frequency. Using 70 cm input to the repeater gets the best distance for the lowest power by those moving around an incident site with hard-hat cameras or portable units. Another advantage to using low-in and high-out at the repeater is that filtering is much easier without strong repeater transmitter harmonics in the receiver.

Antenna separation of 5 feet is usually enough when running a less than 5-W, low-in/high-out portable repeater. Compact 10-dBd gain corner reflectors (barbeque grill antennas) or higher gain beams on 23 cm will extend communication.

With weaker signals, a low-pass filter in the 70 cm receiver feed line and a high-pass filter in the 23 cm transmitter feed line may help to minimize desensitization. If a portable ATV repeater system is used at or near a communications site, band-pass filters in the antenna feed lines should be used to prevent intermodulation interference or receiver overload from nearby transmitters.

Construction details for a typical portable ATV repeater can be found at **www.hamtv.com/info.html** under Portable Public Service Repeater.

5.6 RF Power Amplifiers for ATV

The requirements for ATV RF power amplifiers depend upon the modulation mode used. However, there is one common requirement: The amplifier must be rated for 100% duty cycle, continuous service. While typical amateur voice communications are mostly receiving with intermittent transmitting, a typical ATV transmission can run for many minutes, to hours in length. (ATV should be treated as 100% duty cycle operation when assessing RF exposure as discussed in the **Safe Practices** chapter.) Recognizing the wide bandwidth of ATV signals, the amplifier should operate across the entire ham band without returning. Tuned amplifiers tend to be too narrow-band for ATV service.

AMPLIFIERS FOR ANALOG ATV

For AM and VUSB TV, very linear amplifiers are required and they must not be driven to their power limits. Sync, color, and sound can be distorted unless the amplifier has been carefully designed for both stability and AM video modulation. A few manufacturers offer special ATV amplifiers or standard models designed for all modes, including ATV.

Non-linearity in the amplifier also creates distortion products which appear outside of the allocated TV channel. For VUSB TV, this becomes very evident in the re-appearance of the lower sideband. It is most noticeable on the 3.58 MHz color and 4.5 MHz sound subcarriers. An acceptable upper limit for amateur service VUSB TV is to keep the lower sideband's suppressed sound carrier (SSC) at least 20 dB below the upper sideband sound carrier. This is usually reached by driving the sync pulse tips up to, but not beyond the –1dB gain compression point of the amplifier. A good, linear amplifier should have a straight-line output versus input power curve with a smooth roll-off as saturation is reached.

Almost all amateur linear power amplifiers exhibit some degree of gain compression from half-power to their full rated PEP output. For proper AM ATV operation, the amplifier can be driven to PEP output power of no more than its 1 dB gain compression level. If more power is needed, the analog AM ATV exciter/modulator can use a sync stretcher to maintain the proper transmitted video-to-sync ratio to compensate for higher outputs.

For FM TV linearity is not required, so Class C amplifiers are preferred for the highest efficiency. The FM amplifier can be driven to full saturated output.

AMPLIFIERS FOR DIGITAL ATV

In DTV service, the quality of transmission is measured by *Modulation Error Rate* (MER). The ideal is to keep the MER better than 40 dB. However, MER is very difficult to measure without sophisticated test instruments. Another indicator of DTV signal degradation is the presence of out of channel noise sidebands, typically measured with a spectrum analyzer. A typical DTV measurement is the *shoulder break point* at which the rectangular pedestal of the DTV signal transitions to the noise skirts. This can also be measured with an SSB receiver and an S meter.

For amateur DTV service, an acceptable compromise between maximizing the output power, acceptable MER, and minimizing out of channel products is to increase the RF drive level until the shoulder break point is –30 dB from the main signal amplitude. For amateur TV repeater service, a band-pass, channel filter is also added.

Class C amplifiers cannot be used for DTV. The amplifier must be either operated as Class A or Class AB. Thus, an ATV amplifier will be much less efficient than a Class C amplifier. Linear amplifiers for ATV and DTV service today mainly use MOSFET transistors.

TV transmitter output power ratings are different depending upon the modulation mode used. For an FM TV transmitter, it's output is constant and the amplifier is driven to maximum saturated output. An FM transmitter is thus rated in terms of average power.

For an AM TV or VUSB TV transmitter, the average power output is variable and depends upon the gray level of the video signal being transmitted. It can vary by several dB. What is constant for this transmitter is the peak power of the TV sync pulses. Thus, an AM or VUSB transmitter is rated in terms of its PEP (Peak Envelope Power). This is the same as the rating on a SSB transmitter.

For a DTV transmitter, there is no easily distinguishable feature, like a sync pulse. Its output is noise-like with random peaks and valleys, but it can be characterized by an average power. Thus, DTV transmitters are characterized by their average power. Depending upon the type of modulation being used the peak to average ratio might be from 8 to 12 dB or more. Thus, to avoid distortion, considerable head room must be provided with a DTV transmitter. It should never be driven hard enough to push the average power close to maximum saturated output power.

As a typical example showing what can be expected in terms of output power, the following are specifications of the KH6HTV model 70-7B MOSFET amplifier shown in Figure 11. (**www.kh6htv.com**) Its maximum saturated output power for CW or FM service is 20 watts (43 dBm). Its –1 dB gain compression point is about 10 Watts (40 dBm) and this is the PEP rating for VUSB TV service. For DVB-T (QPSK) service, it is rated at 3 watts, average (35 dBm). This is at the –30 dB shoulder break point. Thus, for DVB-T service, a minimum headroom of at least 8 dB is required.

5.7 Antennas for ATV

The key criteria for selecting an antenna for ATV service is bandwidth. Because of the broad spectrum required for ATV, the antenna's bandwidth must be equally wide and preferably flat across the entire amateur band to allow flexibility in changing TV channels. A number of manufacturers make beam antennas designed for ATV use that cover the whole band from 420 to 450 MHz.

If the antenna manufacturer cannot give you information on gain and VSWR versus frequency, then you will need to rely upon recommendations from your ATV peers and antenna articles published in ATV magazines. For the 70 cm band, for example, many of the really high-gain Yagi antennas were optimized for the weak signal, SSB and CW, frequencies near 432 MHz. They have high gain, but narrow bandwidths. Many vertical, omni, base station antennas were designed specifically for the upper 10 MHz of the band (440 – 450 MHz) for use with FM voice repeaters. They worked well there, but very poorly at the bottom end of the band. The popular "barbeque grill" antennas are available for the 70 cm and higher frequency bands, as well.

Whether to use horizontal or vertical polarization is always a question. Using the wrong polarization immediately results in at least a –20 dB penalty. For ATV, there is not a standard polarization. Some ATV groups are using vertical while others are using horizontal. If there is already an active ATV group in your area, then the obvious choice is to use what they are using.

Foliage greatly attenuates signals at UHF, so place antennas above the treetops for the best results. Use low-loss feed line and weatherproof all outside connectors. Almost all ATV antennas use N connectors, which are more resistant to moisture contamination than other types. See the **Transmission Lines** chapter for help with appropriate cable and connectors.

5.8 ATV Suppliers

Table 1 lists suppliers of ATV equipment in early 2022. It is by no means complete. Many other suppliers can be found by online searches including online retail and auction sites.

Listing here does not imply endorsement by the ARRL nor the author, KH6HTV. The list is arranged alphabetically.

Table 1
ATV Suppliers

Supplier	*Website*	*Country*	*Notes*
ATV Research	**www.atvresearch.com**	USA	Distributor of commercial security video equipment CATV modulators and receivers, etc.
Boulder Amateur TV Club	**www.kh6htv.com/newsletter**	USA	Free ATV monthly newsletter
British Amateur TV Club	**batc.org.uk**	U.K.	DTV kits, free streaming service for ATV repeaters, ATV magazine for members
Comet	**www.cometantenna.com**	Japan	Antennas
CQ-DATV	**www.cq-datv.mobi**	U.K.	Free, on-line ATV magazine
DATV Express	**www.datv-express.com**	USA	DVB-S receiver and transmitter boards
DCI	**www.dci.ca**	Canada	RF filters, including ATV BPFs
Diamond	**www.diamondantenna.net**	Japan	Antennas
Directive Systems	**www.directivesystems.com**	USA	VHF/UHF and microwave antennas
Down East Microwave	**www.downeastmicrowave.com**	USA	RF products from 50 MHz to 10 GHz, amplifiers, preamps, transverters, etc.
DKARS	**www.kdars.nl**	Holland	ATV & amateur radio magazine
Hi-Des	**www.hides.com.tw**	Taiwan	Low-cost DVB-T modulators and receivers
Intuitive Circuits	**www.icircuits.com**	USA	OSD-ID board, DTMF decoder, analog ATV repeater controller board
KH6HTV Video	**www.kh6htv.com**	USA	70, 33, and 23 cm RF power amplifiers, preamps, ATV/DTV application notes
KUHNE Electronics	**www.kuhne-electronic.de**	Germany	Power amplifiers, preamps, converters, oscillators, transverters
L-Com	**www.l-com.com**	USA	Microwave antennas
MFJ	**www.mfjenterprises.com**	USA	70 cm, VideoLynx AM TV transmitters
MiniKits	**www.minikits.com.au**	Australia	70 cm, AM TV & 1.2/2.4 GHz FM TV transmitter kits, RF amplifier kits
Mirage	**www.mirageamp.com**	USA	RF power amplifiers
M-Squared	**www.m2inc.com**	USA	Antennas
OE7DBH	**oe7dbh@tirol.com**	Austria	RF power amplifiers
OREI	**www.orei.com**	USA	HDMI A/V accessories
P.C. Electronics	**www.hamtv.com**	USA	Former supplier of AM TV transmitters; ATV application notes
PE1RKI	**www.pe1rki.com**	Holland	High-power microwave amplifiers, pre-amps, filters, and antennas
SR-Systems	**www.sr-systems.de**	Germany	DTV cards
SuperPass	**www.superpass.com**	Canada	Microwave patch antennas
TV-AMATEUR	**agaf-ev.org**	Germany	ATV magazine
W6PQL	**www.w6pql.com**	USA	High-power amplifiers

6 Slow-Scan Television (SSTV) Overview

The previous sections discussed fast-scan amateur television, used to send wide-bandwidth full motion video on the 420 MHz and higher frequency bands. In contrast, slow-scan television (SSTV) is a method of sending still images in a narrow bandwidth widely used on the HF bands. SSTV activity can be found on HF, VHF, UHF, repeaters, satellites, VoIP on the internet, and by almost any means that can transmit and receive a voice signal.

Images are our most powerful communication tool. SSTV allows us to add images to our verbal communications via amateur radio. Working with the SSTV mode can provide much more than just swapping pictures. It provides a practical way to learn about radio propagation, computers, and computer graphics. The more involved you become, the more you learn about its intricacies.

SSTV is also a great way to get others involved in amateur radio and to enhance other activities. Consider adding SSTV capability to your emergency communications, public service, Field Day, or Jamboree on the Air station. SSTV is a legacy mode that is enjoyed by many hams worldwide. More and more hams are finding this older mode appealing and it is also used by public service teams to support disaster response and recovery efforts.

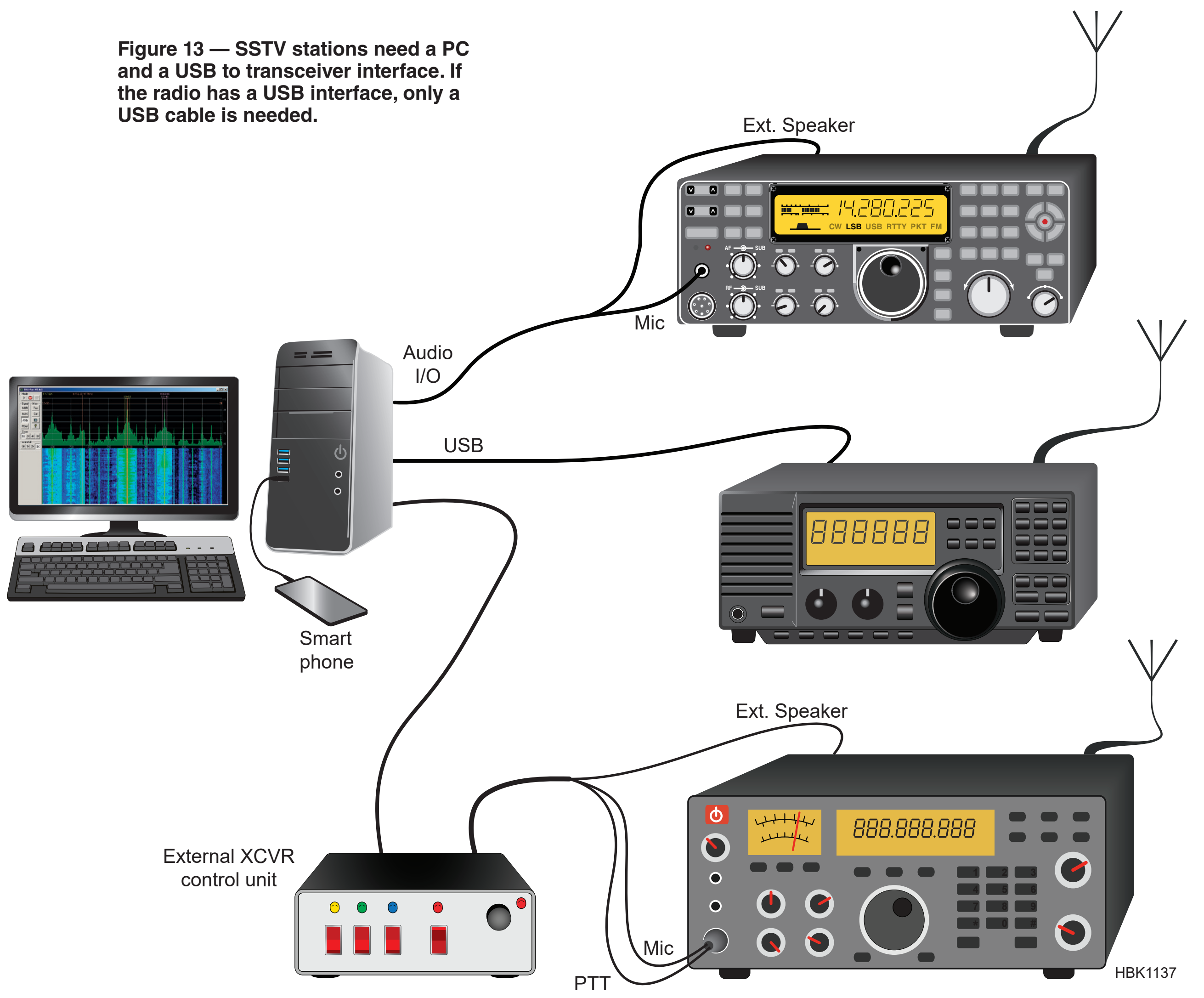
Figure 12 — First cross-Atlantic SSTV transmission in 1959.

This section of the *Handbook* is intended to provide an overview of SSTV signals, operation, and equipment configuration. The *SSTV Handbook* by Martin Bruchanov, OK2MNM, is a very thorough resource on all aspects of SSTV and may be downloaded at **www.sstv-handbook.com**.

6.1 SSTV History

SSTV originally involved the transmission of a visual image from a live video source. Images were black-and-white. Specific audio

Figure 13 — SSTV stations need a PC and a USB to transceiver interface. If the radio has a USB interface, only a USB cable is needed.



tones represented black, white, and shades of gray, and other audio tones were used for control signals. The receiving station converted the tones back into an image for display on a picture tube. It took 8 seconds to send a picture, and everything fit in the same bandwidth used for SSB transmissions.

Cop Macdonald, WA2BCW/VY2CM, developed the first SSTV system, receiving the Dayton Hamvention's Technical Excellence Award in 2009 for his SSTV development work. **Figure 12** shows the first SSTV image sent across the Atlantic Ocean to John Plowman, G3AST, by MacDonald in 1959.

For the initial system, MacDonald used a surplus long-persistence phosphor radar monitor to display the images. The images were captured using a vidicon camera or a flying-spot scanner. One frame of video had 120 lines and was sent at a rate of 15 lines per second, requiring 8 seconds per frame. Three frames were sent back-to-back to maintain an image on the monitor. For many years, bulky and complex home-built systems were the only way to participate in SSTV.

Robot Research produced SSTV equipment throughout the 1970s and 1980s. The Robot 1200C scan converter, introduced in 1984, represented a giant leap forward for SSTV — all the SSTV functions were performed within a single piece of equipment. A *scan converter* converts signals from one video format to another. In this case, it converted SSTV signals to and from formats intended for fast scan television. This allowed the use of standard video cameras and equipment to capture and display images.

DOS-based PCs became a popular component for SSTV systems in the early 1990s. These hybrid systems were part hardware and part software. Most systems required external equipment to process the audio and perform the analog-to-digital conversion. In 1998, the Tasco Electronics TSC-70 Telereader color scan converter was used on the MIR space station to send pictures from space. Kenwood introduced Visual Communicator VC-H1, a portable SSTV unit that included a built-in camera and LCD monitor. Other scan converters were made, but none are produced today.

Today, all SSTV communications are performed using a PC connected to a transceiver as shown in **Figure 13**:

1) directly with a USB cable using an audio codec

2) via the PC's soundcard (analog audio)

3) via an aftermarket USB to transceiver interface (standalone modem or digital interface). SSTV software for sending and receiving handles all transmission, reception, image processing, logging, and radio control. The SSTV program functions similarly to software for FT8 or RTTY operating.

7 SSTV Basics

Traditional SSTV is an analog mode, but in recent years digital SSTV has been developed. Both make use of standard voice amateur transceivers — no special radio gear or antennas are required. SSTV transmissions occupy only the bandwidth of voice signals and are allowed on any frequency in the HF and higher bands where image emissions are permitted. These are generally the same band segments used for SSB voice signals.

7.1 Computer to Transceiver Interface

SSTV communications are performed using a computer and a sound card with a connection to the transceiver (see Figure 13). A PTT function is also desirable (but not necessary) with a COM port connection. Newer radios support the *USB Audio Codec* (a digital interface for audio that is a part of the USB standard), so a direct USB connection to the computer is all that is required. Otherwise, the computer's sound card's analog audio input and output will be used. An aftermarket USB-to-transceiver interface can also be used. If the computer is already connected to the radio for other digital modes such as RTTY or FT8 (see the **Digital Communications** chapter), then the connection work has already been done and only configuration of the SSTV software is necessary. (See the **Transmitting** chapter for more information on using computer audio.)

USB INTERFACE

If your transceiver supports the USB Audio Codec, then you can connect your computer directly to the radio and no other ancillary equipment is needed. (The transceiver port is usually a USB "B" connector type, one commonly found on printers.) Before you make the USB connection between the computer and radio for the first time, you will need to download the radio manufacturer's USB Audio Codec driver. Go to the manufacturer's website and find the driver, download, and install it on your computer. Then connect the radio to the computer with the USB cable. Typically, you will need to configure both the SSTV software and the radio for them to communicate. Select the USB Audio Codec device for both Playback (transmission) and Recording (reception), select a COM port for the PTT function, and then set the volume levels for both sending and receiving.

ANALOG INTERFACE

If your radio does not have an appropriate USB interface, then you can use the computer's sound card for transmitting and receiving audio and using VOX to trigger the transceiver's transmit function; or you may obtain an interface unit that connects to your computer's USB port and provides audio out, audio in, and PTT functions for the radio.

Interfacing the transceiver to the PC sound card can be performed by connecting a couple of audio cables. Sound cards generally have miniature (1/8-inch) stereo phone jacks, so use matching plugs when making these connections. Only one audio channel is required or desired — the left channel. This is the tip connection on the plug. Use shielded cable with the shield connected to the sleeve (ground) on the plug. Hum or buzz from ground loops may be avoided by bonding equipment together or by using an audio isolation transformer. (See the **Digital Communications** chapter for examples of how to connect the transceiver and PC.)

The connection for received SSTV audio from the transceiver may be made anywhere that received audio is available. The best choice is one that provides a fixed or *line level* audio output. This will ensure that recording control levels will not have to be adjusted each time the volume on the transceiver is adjusted. You can use a headphone or speaker output if that's all that is available. If the received output level is enough for the LINE IN input on the sound card, use it, otherwise use the MICROPHONE input. If the level is too high for LINE IN, an attenuator may be required.

Use the LINE OUT connection on the sound card for transmitted SSTV audio. (See the **Digital Communications** chapter's examples for AFSK signals.) If the transceiver does not have a separate input for the audio signal, the microphone input must be used. This requires a more elaborate interface.

Transmit-receive (TR) keying can be controlled using the transceiver's VOX. Other methods for activating transmit include manual switching, a serial port circuit, an external VOX circuit, and/or a computer-controlled digital signal output connected to the transceiver's PTT input.

AFTERMARKET USB INTERFACES

Fully assembled and kit sound card interfaces are available commercially. Most of the sound card interfaces for the digital modes are suitable for SSTV. The microphone will be used regularly between SSTV transmissions, so consider how to conveniently switch back and forth between voice and SSTV operation.

HARDWARE AND SOFTWARE CONFIGURATION

Hardware and software setup for SSTV is similar to that described for sound card modes in the **Digital Communications** chapter, including the sound card characteristics. Most sound cards will work, but sample rate accuracy is important for some SSTV modes (more on this later). Within *Windows*, the MASTER VOLUME and WAVE controls set the levels for the transmitted SSTV audio. All other mixer inputs should be muted. Equalization and special effects should not be used. *Windows* sounds should be disabled to prevent them from being transmitted along with the SSTV audio. The RECORDING control panel is used to select the input for receiving the SSTV audio. Adjust the LINE IN or MICROPHONE settings as needed to achieve the proper level. MIC BOOST should not be used.

7.2 Transceiver Requirements

An SSB voice transceiver with a stable VFO is necessary for HF SSTV operation. The VFO should be calibrated and adjusted to be within 35 Hz of the carrier or "dial" frequency (more on this later). SSTV is transmitted as SSB on the HF bands, using the same sideband normally used for voice. FM is used on the VHF and UHF bands and any modern FM voice transceiver will be adequate for SSTV.

The transceiver's audio bandwidth should not attenuate the audio spectrum used by SSTV. Filters should be set to 3 kHz or wider. Turn off functions that affect audio bandwidth or linearity, such as transmit or receive audio equalization, noise blanker or noise reduction functions, compression or speech processing, and passband tuning or IF shift. Sub-audible access tones or DSC codes on FM transmissions may disrupt image reception and are generally not required for SSTV operation.

Adjust the transmitter output for proper operation with the microphone first, according to instructions in your manual. Then connect and adjust the computer's sound card output for the desired audio level. ALC action should be minimal or none. Properly adjusted levels and clean audio quality will improve the reception of the transmitted signal and reduce interference on adjacent frequencies.

SSTV transmissions are 100% duty cycle when an image is being sent. Image transmissions can last as long as two minutes. If your transceiver is not designed for extended full-power operation, reduce the power output to one-half its maximum output.

MINIMIZING INTERFERENCE

The SSTV audio signal has its lowest tone (the sync pulse) at 1200 Hz and the highest tone (white) at 2300 Hz. Since the tones are modulated, an extra 200 Hz of guard band is advisable, so the entire audio bandwidth is from 1000 to 2500 Hz. On crowded bands, especially 20 meters, adjacent voice contacts are often conducted with sidebands extending from 14.228 to 14.231 MHz which will overlap the bottom 1000 Hz of an SSTV signal with a carrier frequency of 14.230 MHz.

To minimize interference, adjust the receiver's passband to have a low cutoff of 1000 Hz and a high cutoff of 2500 Hz. For receivers with shift and width adjustments, set the center frequency to 1750 Hz and width to 1500 Hz. Set the AGC time constant to its "fast" setting.

Note that when you make this passband adjustment you won't be able to understand voice transmissions. Many newer transceivers have "band stack" memories, often three per band, allowing you to have one memory for SSB, one for CW, and one for digital. If possible, use one for your SSTV setup and adjust the passband, power output and input connections as well as frequency specifically for SSTV. A dedicated standalone memory channel can also be used.

7.3 SSTV Operating Practices

Analog SSTV operation is similar to voice communication with one important difference: a transmission takes anywhere from 30 to 120 seconds to complete. Typically, a station seeking an SSTV contact transmits a CQ image showing their call sign and waits for a response. On 14.230 MHz especially, the old practice of calling CQ by voice is no longer common. Stations should not "broadcast" by transmitting an image without there being a receiving station. Voice conversations with another SSTV station should move to another frequency to keep the SSTV calling frequency of 14.230 MHz clear for the next image.

MAKING AN SSTV CONTACT

A typical SSTV contact consists of the following: the initiating station sends a CQ image, the responding station sends back a signal report image, the first station sends a signal report image, the second station sends a 73/thanks image, and the first station concludes the contact with their own 73/thanks image. (Signal reporting is described in the Analog SSTV section.)

Since most worldwide SSTV operation occurs on one frequency (14.230 MHz), at times there can be many stations wanting to make contact. When other stations are present, the five-image sequence can be abbreviated by one or both stations sending an image combining the signal report/73/Thanks. This is often done when the stations have contacted each other before as is common among SSTV enthusiasts.

When selecting images to send, consider appropriateness, picture quality, and interest to the recipient. Choose an SSTV mode that is suitable for the image to be sent and band conditions. Avoid using ScottieDX or other SSTV modes which require more than two minutes of transmission time to avoid occupying the frequency for an excessive period. Sending a CW or voice station ID is not necessary if your call sign is included in the image.

To send an SSTV image, use your software to select and load a picture to send. It will be displayed in a transmit screen. Next, select the SSTV transmission mode. Initiate the transmission and your transceiver will switch to transmit and send the SSTV audio. When the SSTV transmission is over, the transceiver returns to receive. Be sure to send the full frame or the next picture sent may not be received properly if the software does not start scanning from the start of the frame.

MANAGING IMAGES

Smartphones and digital cameras the most popular image source along with the internet. (If an image is copyrighted, you can transmit it but not claim it as or incorporate it in your own work.) The subject matter could be almost anything that you might have available. Pictures of the station, equipment, and operator are always welcome. A live camera or web cam can provide a quick snapshot.

For those who like to discuss technical details, diagrams and schematics might be your chosen subject. A flatbed scanner is ideal for importing diagrams, schematics, and photographs. Screen shots of what is on the computer monitor can be saved simply by using the PRINT SCREEN or PRTSCRN key. Use the Paste function in *Windows* to transfer the image to your SSTV or image editing software.

Include your own personal drawings. Make your images colorful with lots of contrast to make them really stand out. You can also transmit pictures of your home, areas of local interest, other hobbies, projects, maps, cartoons, and funny pictures. Any image editing program can be used to make your own CQ image, test pattern, video QSL card, or "73" picture.

Create a dedicated directory on your computer to store all the pictures you may want to use in either JPEG or BMP format. The resolution does not have to be high. Cropping or sizing the picture to 320 × 256 pixels is usually sufficient. There's no need to embed text into the original picture. Rather, use the SSTV software to add a text or "template" layer over the picture for your call sign, location, signal report, etc. For example, in the popular program *MMSSTV*, click on the TX tab and then right-click in the image area and select "Load From Image." After selecting the picture, click on the TEMPLATE tab. Below the image are buttons for adding lines, boxes, text, inset picture, etc. Note that only one line of text can be added at a time and each text line requires its own box. There are several fonts to choose from with bold and italics options.

It is common to have call sign, location, and perhaps a short description as text on the picture. If two call signs are placed on an image, the sender's call sign is commonly placed last. Signal reports may also be included. This information is not typically embedded in the image. Instead, the SSTV software has a text editor to overlay this variable data on to the selected picture before each transmission.

8 Analog SSTV

SSTV is a video mode that uses analog frequency modulation. Every different brightness level in the image corresponds to a different audio frequency. The modulating frequency ranges from 1500 to 2300 Hz, corresponding to the brightness of the video component. The frequency of video signal varies from black by shades of gray to white. The amplitude of the signal does not affect the brightness, only the signal-to-noise ratio (SNR) of the signal. Color is achieved by sending the brightness of each RGB color component separately. The original image is scanned from left to right, in green, blue and red order for Martin and Scottie modes.

Although SSTV is an image signal mode, the format of the signal by which brightness and color are encoded is also called a mode. The various modes have different resolutions and scan rates. **Table 2** contains a summary of SSTV modes for both black and white (B&W) and color. Color SSTV images are the standard today. (See the chapter "Formats of slow-scan TV transmission" in OK2MNM's *SSTV Handbook* in the references listings for a complete description of SSTV image signals.)

TRANSMISSION QUALITY

The quality of the received image depends on the time it takes to transmit the picture, all other aspects being equal: Double the time and double the quality. This is because the structure of noise in SSTV is horizontal. The longer the transmission time, the fewer number of lines are disturbed by a period of noise or fading. This creates a tendency to choose the SSTV method (or mode) with the longest possible transmission time. This clashes with getting as many pictures transmitted in the shortest amount of time, especially on the popular frequencies.

Although there are two dozen SSTV modes available only a few are recommended: Scottie1, Scottie2, Martin1, Martin2 and ScottieDX. Martin1 and Scottie1 are roughly 2 minutes long, Martin2 and Scottie2 are roughly 1 minute long, and ScottieDX takes 4.5 minutes. Only use ScottieDX when you are responding to a station under very poor conditions. Never call CQ with ScottieDX on a popular SSTV frequency.

When calling CQ DX or operating under less than optimum conditions, Scottie1 or Martin1 are the best choices. If conditions are good to very good then Martin2 or Scottie2 can be used to save time. See Table 2 for the transmission times of each mode.

8.1 Color SSTV Modes

Two popular modes for sending and receiving color SSTV pictures are called Martin and Scottie (named after their developers — see Table 2). During a three-day study in 2014, 89 percent of the images received worldwide at WB9KMW were from these two modes. Within each family are several different varieties, for example Martin 1, Martin 2, Scottie 1, and Scottie 2.

Information about the size or resolution for each mode is generally available in the SSTV software. Slower scan rates can provide better quality; those are the modes that take longer to send for the same resolution.

Table 2
Analog SSTV Modes

Family	*Developer Name*	*Sub-mode*	*Color*	*Time*	*Lines*
AVT	Ben Blish-Williams, AA7AS / AEA	8	BW or 1 of R, G, or B	8 s	128×128
		16w	BW or 1 of R, G, or B	16 s	256×128
		16h	BW or 1 of R, G, or B	16 s	128×256
		32	BW or 1 of R, G, or B	32 s	256×256
		24	RGB	24 s	128×128
		48w	RGB	48 s	256×128
		48h	RGB	48 s	128×256
		104	RGB	96 s	256×256
Martin	Martin Emmerson, G3OQD	M1	RGB	114 s	240*
		M2	RGB	58 s	240*
Robot	Robot SSTV	8	BW or 1 of R, G or B	8 s	120
		12	YUV	12 s	128 luma, 32/32 chroma × 120
		24	YUV	24 s	128 luma, 64/64 chroma × 120
		32	BW or 1 of R, G or B	32 s	256 × 240
		36	YUV	36 s	256 luma, 64/64 chroma × 240
		72	YUV	72 s	256 luma, 128/128 chroma × 240
Scottie	Eddie Murphy, GM3SBC	S1	RGB	110 s	240*
		S2	RGB	71 s	240*

*Martin and Scottie modes actually send 256 scan lines, but the first 16 are usually grayscale.
Data courtesy of Wikipedia's entry on Slow-Scan Television at **en.wikipedia.org/wiki/Slow-scan_television**

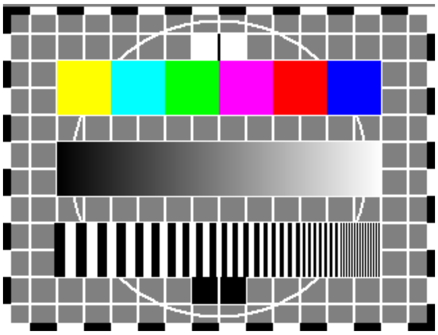


Figure 14 — This color test pattern is 320 × 256 resolution. The Robot modes from the 1980s only used 240 lines. CRTs were 4:3 aspect ratio, so the images were displayed in 320 × 240 resolution. When Scottie 1 and Martin 1 modes were added, they kept this resolution but added 16 header lines to the top to aid in synchronization. These 16 header lines, shown as the solid gray area at the top, are now used as part of the image and include the sender's call sign and other information.

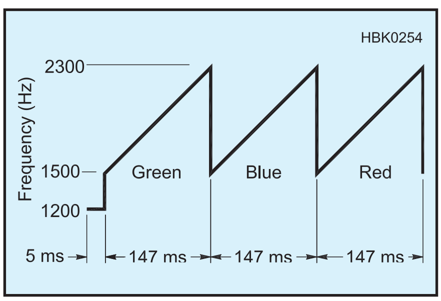


Figure 15 — This is a diagram of a single scan line of a Martin 1 transmission. The full frame includes 256 horizontal scan lines starting at the top. Before each line, a 1200 Hz tone for 5 ms is sent for synchronization. The pixels are scanned left to right, and the colors are sent sequentially. First the green component is sent for each of the 320 pixels of one scan line — 256 values are possible from black to pure green. Next, is the blue component, and the red component is sent last (again, 256 possible values for each color). It takes 147 milliseconds to send each of the three color components. The result is 114 seconds to send the complete frame.

For example, Scottie 1 and Martin 1 are popular RGB (red, green, blue) color modes that take about two minutes to send a frame. The image size sent is 320 × 256: 320 pixels across with 256 lines. See **Figures 14** and **15**. True color is possible since each pixel is sent with 256 possible levels for each of the three different color components, red, green and blue.

Each mode has a *vertical interval signaling* (VIS) code that identifies the mode being sent. The code is sent during the time between frames, called the *vertical interval*. The VIS codes use 1100 Hz for 1, 1300 Hz for 0, and 1200 Hz for start and stop. When a VIS code is received, the receiving system configures itself for the proper SSTV mode.

For VIS code detection to work, the receiver must be tuned within 70 Hz of the transmitted frequency. Two stations tuned exactly on the SSTV frequency but with VFO errors of +35 Hz and –35 Hz could successfully pass the VIS codes. As mentioned previously, each transceiver must have the VFO and display calibrated within 35 Hz to ensure VIS code detection with the transceiver set to the SSTV frequency. Using the sync pulse rate is another way to determine the mode when the VIS is not decoded. If a sender is far off frequency, use the 1200 Hz sync signal in the spectrum or waterfall as a guide to adjust the VFO. Transceivers with accurate, stable VFOs are highly recommended for SSTV.

Received images are displayed in near real time as they are decoded. Almost any SSTV signal that is heard can produce an image, but it is rare to receive an image that is perfect. Changes in propagation, noise, and other interferences will become apparent as the image continues to scan down the screen. Noise will damage the lines received just as it occurs. Interference from other signals will distort the image or perhaps cause reception to stop. Signal fading may cause the image to appear grainy. Multipath will distort the vertical edges. Selective fading may cause patches of noise or loss of certain colors.

Images that are received with staggered edges are the result of an interruption of the sound card timing. Check with other operators to see if they also received the image with staggered edges. If not, then it may be your computer that has the problem and not the sending station. Some possible solutions are to close other programs, disable antivirus software and reboot the computer.

8.2 Communicating in Color

Remember, picture quality can be quite poor at the receiving station because signals often deteriorate significantly due to propagation, noise, and other factors. Receiving operators can take steps to maximize the image quality. The two most important factors are font size for characters and color contrast.

When sending, choose a large text font so the text can be read even in the presence of noise. Then for high visibility and readability of text in the image, high contrast is crucial. Problems arise from the choice of pastels and less than distinct color combinations. The top four most visible color combinations are black text on a yellow background, black over white, yellow over black and white over black.

When attempting to communicate effectively via SSTV, do the following:

• Keep it simple. Keep the wording short and succinct.

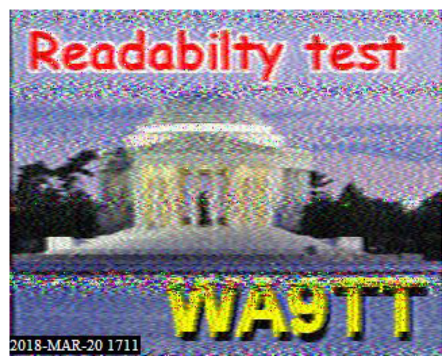
• Keep it big. Large text allows hams to view your message clearly.

• Keep it clean. Avoid using thin fonts, as well as most script fonts. Use thick, heavy fonts to maximize readability.

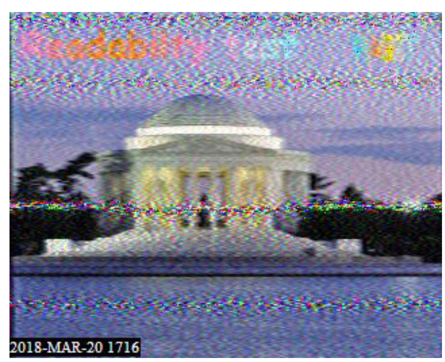
• Keep it colorful. High color contrast is key.

Figures 16A and **16B** illustrate how readability is affected by font size and color contrast, as copied by a distant station. Both images carry the same text message.

Clear, easy to read text is especially important if you are trying to work DX. Sometimes only extremely simple monochrome images — or even a black background — with large contrasting letters is the only way get the message across. For example, sending an image in Martin1 or Scottie1 with only three lines



(A)



(B)

Figure 16 — Text is easiest to read when properly sized and contrasts well with the image background as shown in (A). The image in (B) is harder to read due to poor choice of font size and color contrast in the presence of noise artifacts in the received image.

Figure 17 — Under difficult conditions or in the presence of noise, simple monochrome images as shown here are the easiest to read.

of large white letters over a black background as in **Figure 17** will get the job done when no other image will. Sending complex, colorful pictures makes it hard to make DX contacts.

8.3 SSTV Signal Reporting

Traditionally, hams have used an RSV system to give an SSTV signal report. This parallels the RST report given on CW and RS for SSB contacts. RSV denotes:

- **R**eadability for the template words
- **S**trength of the transmission
- **V**ideo quality

R = 5 is perfectly readable text. S = 9 denotes an extremely strong signal. V = 5 means the video is crystal clear without any blemishes. Although 595, 575, and the occasional 555 report are given, a true V = 5 image is fairly rare. Thus, the traditional RSV signal reporting system does not provide a lot of information to the transmitting station operator.

An alternative SSTV reporting P-quality system is gaining in popularity similar to the reporting system for fast-scan ATV. There are six levels from P5 to P0. These levels are based on image research that assigned data quality rating compared to an original image.

Figure 18 — P5: Broadcast quality

Figure 19 — P4: Good, some noise

Figure 20 — P3: Usable, but noisy.

- P5: 100% to 97.7% received, broadcast quality with minimal distortion (see **Figure 18**).
- P4: 97.7% to 84.1% received, a good image with a few noise lines (see **Figure 19**).
- P3: 84.1% to 50% received, the most common image quality on 20 meters. These pictures are usable but noisy (see **Figure 20**).
- P2: 50% to 15.9% received, the SSTV signal is not strong enough to overcome the noise. These images are quite noisy and barely usable (see **Figure 21**).
- P1: 15.9% to 2.3% received, images during poor signal reception. One can barely see the text and the picture is far from distinct (see **Figure 22**).
- P0: 2.3% to 0% received, images are totally unusable (see **Figure 23**).

Figure 21 — P2: Barely usable, noisy.

Figure 22 — P1: Text is barely visible.

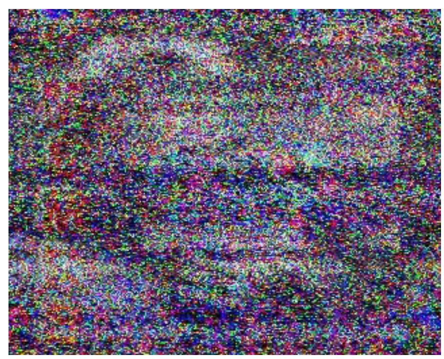


Figure 23 — P0: Unusable

8.4 SSTV Cams

A few hams around the world routinely monitor SSTV transmissions, typically on 14.230 MHz, and then immediately post that information on website servers for display online. These sites are referred to as "SSTV

Figure 24 — Image received from the International Space Station.

Table 3
SSTV Frequencies

Analog

Band (Meters)	*Frequency (MHz)*	*Modulation*
160	1.890	LSB
80	3.845, 3.730 in Europe	LSB
40	7.171, 7.040 in Europe	LSB
20	14.230	USB
17	18.117	USB, N-SSTV (see text)
15	21.340	USB
12	24.927	USB, N-SSTV (see text)
	24.975	USB, All modes
10	28.680	USB
2	145.500	FM
ISS SSTV Downlink	145.800	FM

Digital

Band (Meters)	*Frequency (MHz)*	*Modulation*
80	3.843, 3.733 in Europe	LSB
40	7.173	LSB
20	14.233	USB
15	21.343	USB

cams." Like the Reverse Beacon Net (RBN), PSKReporter, and WSPRNet systems, some stations go further by collecting SSTV cam images and aggregating those images onto one web page for viewing. (Search online for "amateur radio SSTV cams" to find these websites.)

This information is helpful in two ways:

1) Propagation. You can view how well your transmission was received by a variety of stations by looking at those SSTV cams. You can immediately assess 20-meter band conditions. You will know which areas are receiving your transmission and where you have no reception.

2) Station relay. During an SSTV QSO, all sorts of things happen, such as QSB, QRM, and QRN. All interfere with your ability to receive the latest transmission. By using these SSTV cams as "relay stations" to supplement your station's reception, you will be able to enjoy a richer QSO. If you receive a very poor image you can also go to the webcam page and perhaps see it with better quality.

8.5 SSTV Operating Frequencies

SSTV operation centers on several frequencies in the HF and VHF range. Use the customary phone sideband for the band being used. Most contacts occur on 20 meters on 14.230 MHz for analog SSTV and on 14.233 MHz for digital SSTV. (Move 3 kHz above or below these frequencies to have an extended contact if the band is busy.) **Table 3** lists a number of popular frequencies used in North America and Europe. Remember that these frequencies are not dedicated to SSTV and may be occupied with other signals. Having a backup frequency or using another band to avoid congestion is good practice.

In the late afternoon and evening hours, regional activity switches to 40 and 75 meters, with some contacts on 160 meters. In the United States, 7.171 MHz and 3.845 MHz are commonly used, although 7.171 MHz is only available to Extra Class licensees.

Locally, a 2-meter SSTV net may be active either on the SSTV calling frequency of 145.500 MHz or perhaps on an FM repeater. (Before using a repeater for SSTV contacts, be sure the repeater owner approves.)

Occasionally the International Space Station will broadcast SSTV pictures on 145.800 MHz. Check **ariss-sstv.blogspot.com** for the operating schedule. A simple antenna and a common FM transceiver can be used for reception as shown in **Figure 24**. ISS passes visible at your location can be determined by a satellite tracking program or via a website such as **heavens-above.com**.

8.6 Narrow SSTV

Due to crowded conditions on 20-meter SSTV, "Narrow SSTV" or N-SSTV has become popular. This is an analog SSTV transmission with an audio signal only 500 Hz wide, extending from 1900 to 2300 Hz. Contrast that with normal SSTV, which has a VIS marker at 1200 Hz and image intensity is transmitted between 1500 and 2300 Hz.

An N-SSTV Group has formed and in accordance with the IARU Band Plan, is promoting N-SSTV on 18.117 MHz USB and 24.927 MHz USB. These are temporary experiments as of early 2022 and the frequencies may change in the future. Broadband modes like Martin and Scottie are not allowed on 12 meters.

Note that the ARRL's understanding of FCC rules is that image transmissions of any type are not permitted on 30 meters, regardless of whether the transmission encoding is digital or analog. For that reason, the ARRL does not include or recommend 30 meters for SSTV emissions of any type although US hams are not prohibited from receiving SSTV transmissions there.

It is useful to enable your software to use the FSKID method of call sign identification during the transmission. The PLL demodulation technique seems to work best for receiving N-SSTV pictures.

N-SSTV is acceptable on the usual SSTV operating frequencies and on 17 meters. It may be used on the 12-meter band as long as you follow the requirements of FCC Part 97.307(f):

(1) No angle-modulated emission may have a modulation index greater than 1 at the highest modulation frequency.

(2) No non-phone emission shall exceed the bandwidth of a communications quality phone emission of the same modulation type.

8.7 Software for Analog SSTV

A variety of software programs are available for SSTV (see **Table 4**). Some multimode programs include SSTV and digital modes, while others are dedicated to SSTV. Remember that sound card sample rate accuracy is

Table 4
SSTV Software

Windows
Analog SSTV
Ham Radio Deluxe DM-780 — **www.ham-radio-deluxe.com/features/dm780/**
MMSSTV — **hamsoft.ca/pages/mmsstv.php**
YONIQ — **radiogalena.es/yoniq/**

Multimode
JVComm32 — **jvcomm.de/index_e.html**
MixW — **www.mixw.net**
MultiPSK — **f6cte.free.fr/index_anglais.htm**

Digital SSTV
DIGTRX — **www.qsl.net/ik1hgi/digital/digitrx.html**
EasyPal — **www.g0hwc.com**

macOS
Black Cat SSTV — **www.blackcatsystems.com/software/sstv.html**
MultiScan — **www.qsl.net/kd6cji/**

Linux
QSSTV — **users.telenet.be/on4qz**
TRXAMADRM — **www.pa0mbo.nl/ties/public_html/hamradio/txamadrm/index.html**

(A)

(B)

Figure 25 — If the sound card clock is inaccurate, analog SSTV images may appear slanted (A). The same image is shown at B after calibrating the clock.

important and received pictures will appear *slanted* if the clock timing is incorrect (see **Figure 25**).

The most popular analog SSTV package is *MMSSTV* by Mako Mori, JE3HHT. For more information or to download a copy, visit **hamsoft.ca/pages/mmsstv.php**. *MMSSTV* will run on old PCs, but some features may require a faster processor. *MMSSTV-Yoniq* by Eugenio Fernandez, EA1ADA, is MMSSTV updated with several improvements. It runs on Windows 10 and is becoming quite popular. Download *YONIQ* by clicking on the link "Descarga de MMSSTV 1.13 YONIQ" on the Grupo Radio Galena website, **radiogalena.es/yoniq**.

The *MMSSTV* Help file includes detailed information on several ways to do a quick and easy calibration (see the Slant Corrections section). The best method is the one that uses a time standard such as WWV. (Before performing this calibration procedure, you must have the sound card interface connected so *MMSSTV* can detect received audio.) After performing the clock calibration, chances are, the timing will also be correct for transmit. If not, *MMSSTV* provides a means for making a separate adjustment for transmit. Alternatively, two other approaches for adjusting receive and transmit slant are discussed in depth in tutorials at **wa9tt.com** titled "That Pesky Slant." Help for analog SSTV is available online at **groups.io/g/MMSSTV**.

9 Digital SSTV

(*As of early 2022, digital SSTV operation is less and less common. The information in this section is presented for the interested reader and may not be applicable to on-the-air practices much longer. – Ed.*)

Several forms of digital SSTV (DSSTV) have been developed, but the modulation method most widely used for digital SSTV is derived from the shortwave broadcast system Digital Radio Mondiale (DRM). (Mondiale is a French word meaning "worldwide.") Like analog SSTV, most activity occurs on 20 meters, specifically on 14.233 MHz. (See Table 2.)

HamDRM by Francesco Lanza, HB9TLK, is a variation of DRM that occupies a 2.5 kHz bandwidth and is used in various programs. The signal occupies from 350 to 2750 Hz (see **Figure 26**). As many as 57 subcarriers may be transmitted simultaneously, all at the same level. Three pilot carriers are sent at twice the level as the others. The subcarriers are modulated using *coded orthogonal frequency division multiplexing* (*COFDM*) and *quadrature amplitude modulation* (*QAM*). Each *main service channel* (*MSC*) frame or segment has a duration of 400 ms and several methods of error correction are used within the segments. (See the **Modulation** chapter for more information on ODFM and QAM.)

HamDRM is not a weak-signal mode like the narrow bandwidth data modes such as PSK31. An S-9 or better signal with little or no noise may be required before the software is able to achieve a sync lock. MSC sync lock is required before any data can be decoded and displayed.

The quality of a DSSTV signal far exceeds that of analog SSTV. Distortion-free images are exact reproductions of the original transmission. However, there are drawbacks:

1) Band conditions. They must be favorable for reception and clear of most QRM and no significant QSB. Strong signals ensure quality reception.

2) Sufficient data segments must be received. When an insufficient number of segments are received, the software will simply fail to decode, and no image will be seen. Contrast that to analog SSTV where a weak image, perhaps P2 quality, can still be displayed even with strong noise or interference. Transmit encoding may be changed to send duplicate or redundant segments. Normally a setting of RS1 or RS2 is used. When band conditions aren't good, a higher setting of RS3 or RS4 may be used, however, this increases

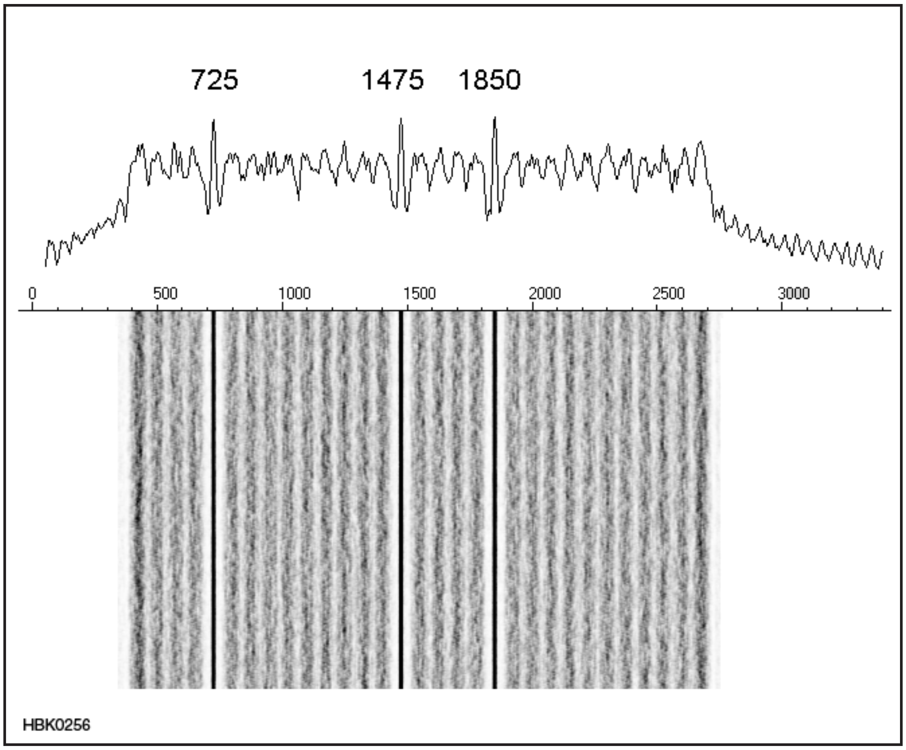


Figure 26 — HamDRM signal spectrum above and waterfall below. Transmissions may have slightly different characteristics due to the many possible submodes. HamDRM transmissions have three pilot carriers with an amplitude twice that of the remaining subcarriers. These pilot carriers are found at 725, 1475 and 1850 Hz and aid in adjusting the frequency of the receiver to match the transmitted signal. Software can compensate for mistuning by as much as ±100 Hz, but only if the offset is stable (little or no drift in frequency). The overall response should be flat, producing a level amplitude across the full spectrum provided that the signal is not affected by propagation. The waterfall should show the same intensity across the full signal. The bandwidth can be as much as 2.4 kHz, starting at 350 Hz and ending about 2750 Hz. Some roll-off can be tolerated.

the transmission time. A receiving station may request re-transmission of missing segments via a *bad segment request* (BSR), or Bad Segment Request. The receiving station transmits the BSR indicating the missing segments to be retransmitted for a "fill" of the picture.

9.1 Digital SSTV Setup

A popular digital SSTV program is *EasyPal* by the late Erik Sundstrup, VK4AES. Digital SSTV uses the same type of PC and sound card setup as for analog SSTV, but a more capable computer is required. For *EasyPal*, a 2 GHz or faster PC running *Windows XP* or newer operating system is required. As soon as the *EasyPal* software is installed, it is ready to receive pictures.

Unlike analog SSTV, the software detects and compensates automatically for clock timing differences so sound card calibration is not required. The software also adjusts for ±100 Hz mistuning.

HamDRM sends the transmitting station's call sign continuously. This may allow others to identify the transmitting station and optimize reception. Many submodes are available, with various transmission speeds and levels of robustness. The submodes are automatically detected and receiving starts automatically. Decoding is done on the fly, so there is no waiting for the computer to finish processing before the image appears.

Power output may appear low as measured by a conventional wattmeter. The actual signal strength as seen by others should be about the same as the SSB voice signal. Do not use dc-blocking capacitors in the audio lines as they may change the phase of the received carriers which disrupts the decoding process.

Audio levels from the sound card to the transceiver are low when using HamDRM and may not trigger a VOX circuit reliably at normal settings. Set the transceiver for full RF output. Then adjust the sound card VOLUME CONTROL output until the transmitter shows little or no ALC indication. With an FM transmitter, keep the output level low to avoid overdeviation. Adjust the VOX GAIN sensitivity for reliable operation.

9.2 Operating Digital SSTV

If you have not operated SSTV before, try analog SSTV before digital. Copy some images to make sure the sound card setup is correct. The level adjustments for analog SSTV are not as critical as those for DRM. Once you have everything set correctly for analog SSTV, it's easier to make adjustments for digital SSTV.

When using digital SSTV, if a sending station is far off frequency, use the pilot carriers as seen in the software spectrum display as a guide. (See Table 3 for digital SSTV frequencies.) Adjusting the VFO while receiving an image is not advised as it will delay synchronization.

The signal-to-noise ratio (SNR) displayed in the software is a measure of the received signal quality. The higher the SNR the better — decoding will be more reliable. Because of the way the software measures the SNR, the peak value displayed for SNR may require 20 to 30 seconds of reception. Adjustments made on either end may change the SNR.

Under very good band conditions the SNR may exceed 18 dB. In that case, a higher speed mode may work. Sub-modes with less data per segment take longer to send, but they are more robust and allow for solid copy even if the SNR is low.

GETTING THE WHOLE PICTURE

Noise and fading may prevent 100% copy of all the segments. Any missing segments may be filled in later. Your software can send a *bad segment report (BSR)* that lists all the missing segments for a file that has been partially received. In response, the other station can send a *FIX* (*resend bad segment request*) which should complete the file transfer. If not, the BSR and FIX process may be repeated.

Digital SSTV is very interactive and may involve several stations on frequency sharing images. FIX transmissions intended for another station may provide some of your missing segments — or even all of them. A third party that copied the original transmission may also send a FIX segment or resend the image. Incremental file repair is possible even after several other transmissions are received. The more stations on frequency, the better the chance that one of them can help out with a FIX.

EasyPal has a feature to provide a higher level of error correction so that 100% copy of all the segments is not necessary to receive the complete file. The transmitted file is encoded with redundant data so that the original file may be recreated even though not all the segments were received. The receiving station must also be running *EasyPal*.

Encoded files have interleaved redundancy using Reed-Solomon (RS) error correction.

(See the **Digital Protocols and Modes** chapter for more information about error detection and correction.) Four different levels of RS encoding may be selected before the file is sent.

Very Light Encode (RS1) is the lowest level. Transmission time for a file using RS1 will be increased by 13%. When receiving a file encoded with RS1, only 90% of the segments must be received before the file can be decoded and a picture displayed. This may happen even before the transmission is complete. Receiving RS encoded files is automatic; there is no need to select it for receive. Decoding of the file received with RS encoding will occur automatically. The use of RS encoding on the HF bands can reduce the need for BSRs and FIXs and has been found to make the file transfer process more efficient. Encoding may not be necessary on noise-free channels such as VHF FM.

Propagation only becomes a factor as it may take longer for the data to get through during poor conditions. The images received will be identical to the ones sent because the data in the files will also be identical. Replays will always be an exact copy. Multipath propagation does not disrupt DRM transmissions unless it is severe or results in selective fading.

Figure 27 shows an *EasyPal* screen following successful reception of an image.

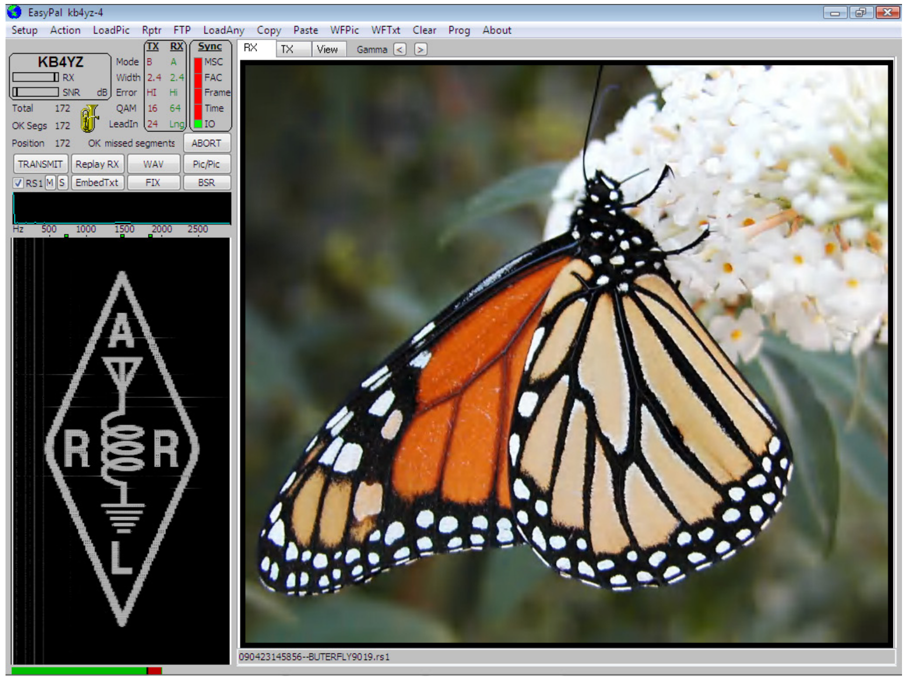


Figure 27 — *EasyPal* digital SSTV software is used to exchange high quality, color images. Several levels of error correction and various transmission speeds are available.

IMAGE SIZE

Pictures of any size or resolution may be sent over digital SSTV. The sending station must pay careful attention to file size, though, or the transmission time may become excessively long. Compressing image files is necessary to get the transmit time down to a reasonable amount. Most images will be converted into JPEG 2000 (JP2), a lossy compression method that shows fewer artifacts. A slider varies the JP2 compression level, and a compromise must be made between image quality and file size. The smaller the file, the more visible the artifacts, but the faster it is sent.

Small image files may be sent without using compression. Some file types such as animated GIF files cannot be compressed, so they must be sent "as is."

A "busy picture" is one that shows lots of detail across most of the image area. This type of picture can be challenging to compress into a file size small enough to send that still maintains acceptable quality. Reducing the resolution by resizing and creating a much smaller image is the solution. Just about any busy picture can be resized down to 320 × 240 pixels, converted into JP2, and still look good when displayed on the receiving end.

About 2 minutes of transmission time is the acceptable limit for the patience of most SSTV operators. A typical HamDRM digital SSTV transmission will take about 105 seconds for a file 23 kB in size, RS1 encoded, and requiring 209 segments.

SENDING DIGITAL SSTV IMAGES

The ideal HamDRM signal will have carriers extending across the 350 to 2750 Hz spectrum. The transceiver should be allowed to pass all frequencies within this bandwidth. In order to maintain the proper phase relationships between all the subcarriers, the signal must be amplified linearly. Avoid overdriving the transmitter and keep the ALC inactive or at the low end of its range. Eliminate hum and other stray signals in the audio.

The process of transmitting an image starts with selecting an image and resizing or compressing it if needed, as described in the previous section. Within *EasyPal*, when the transmit button is clicked, the image file will be RS encoded if that option is selected. Then the resulting file will be broken down into segments and sent using HamDRM.

In receiving HamDRM, the audio is decoded and segments that pass the error check will have their data stored in memory. When enough of the segments are successfully received, the RS file is decoded, and the JPEG 2000 image file is created. The content of this file should be identical to the JPEG 2000 image file transmitted.

It can be quite gratifying to receive your first digital SSTV picture. A lot has to go just right, and there is little room for error. Propagation and interference can disrupt the signal. There is no substitute for a low-noise location and good antenna when it comes to extracting the image. Be patient and when the right signal comes by you will see the all the lights turn green and the segment counter will keep climbing resulting in an excellent picture!

10 Glossary of SSTV Terms

ANALOG SSTV TERMS

AVT — Amiga Video Transceiver. 1) Interface and software for use with an Amiga computer; 2) a family of transmission modes first introduced with the AVT product.

Back porch — The blank part of a scan line immediately following the horizontal sync pulse.

Chrominance — The color component of a video signal. Robot color modes transmit pixel values as luminance (Y) and chrominance (R – Y [red minus luminance] and B – Y [blue minus luminance]) rather than RGB (red, green, blue).

Demodulator — For SSTV, a device that extracts image and sync information from an audio signal.

Field — Collection of top-to-bottom scan lines. When interlaced, a field does not contain adjacent scan lines and there is more than one field per frame.

Frame — One complete scanned image. The Robot 36-second color mode has 240 lines per frame.

Frame sequential — A method of color SSTV transmission that sent complete, sequential frames of red, then green, and blue. Now obsolete.

Front porch — The blank part of a scan line just before the horizontal sync.

Header — The information preceding the main signal that holds information about the picture. This is essential to successful reception.

Interface —The electronic equipment that connects, or interfaces, your computer to the transceiver.

Interlace — Scan line ordering other than the usual sequential top to bottom. AVT "QRM" mode is the only SSTV mode that uses interlacing.

Line sequential — A method of color SSTV transmission that sends red, green and blue information for each sequential scan line. This approach allows full-color images to be viewed during reception.

Luminance — The brightness component of a video signal. Usually computed as Y (the luminance signal) = 0.59 G (green) + 0.30 R (red) + 0.11 B (blue).

Martin — A family of amateur SSTV transmission modes developed by Martin Emmerson, G3OQD, in England.

Pixel — Picture element. The dots that make up images on a computer's monitor.

P7 monitor — SSTV display using a CRT having a very-long-persistence phosphor.

RGB — Red, Green, Blue. One of the models used to represent colors. Due to the characteristics of the human eye, most colors can be simulated by various blends of red, green, and blue light.

Robot — (1) Abbreviation for Robot 1200C scan converter; (2) a family of SSTV transmission modes introduced with the 1200C.

Scan converter — A device that converts one TV image format to another. For example, the Robot 1200C converts SSTV to and from FSTV.

Scottie — A family of amateur SSTV transmission modes developed by Eddie Murphy, GM3SBC, in Scotland.

SNR—Signal-to-Noise Ratio. The higher the SNR, the clearer the received signal.

SSTV — Slow Scan Television. Sending still images by means of audio tones using transmission times of a few seconds to a few minutes.

Sync — That part of a TV signal that indicates the beginning of a frame (vertical sync) or the beginning of a scan line (horizontal sync).

VIS — Vertical Interval Signaling. Digital encoding of the transmission mode in the vertical sync portion of an SSTV image. This allows the receiver of a picture to automatically select the proper mode. This was introduced as part of the Robot modes and is now used by all SSTV software designers.

Waterfall — This is a representation of the received (or transmitted) signal. It is displayed as a moving image that scrolls downward in the SSTV software as time progresses.

Wraase — A family of amateur SSTV transmission modes first introduced with the Wraase SC-1 scan converter developed by Volker Wraase, DL2RZ, of Wraase Electronik, Germany.

DIGITAL SSTV TERMS

Bad segment report (BSR) — A BSR is sent by the receiving station when an image is not received completely. Once the BSR is received a FIX screen is shown allowing the transmitting station to select the picture to fix or simply fix the last image sent. Only bad segments will be resent.

COFDM — Coded Orthogonal Frequency Division Multiplex, a method of using spaced subcarriers that are phased in such a way as to reduce the interference between them, plus coding to provide error correction and noise immunity.

Constellation — A set of points in the complex plane that represent the various combinations of phase and amplitude in a QAM or other complex modulation scheme.

Cyclic redundancy check (CRC) — A mathematical operation. The result of the CRC is sent with a transmission block. The receiving station uses the received CRC to check transmitted data integrity to determine if the data received is good or bad.

Digital Radio Mondiale (DRM) — A system for digital sound broadcasting in bands between 100 kHz and 30 MHz developed by a consortium of broadcasters, manufacturers, and research and governmental organizations. Amateurs use a modified version (HamDRM) for sending digital voice and images.

Error protection — DRM submode selection. The HI level provides a greater amount of **FEC** used within the segment.

Fast access channel (FAC) — Auxiliary channel always modulated in 4QAM. Contains the submode and station information.

FIX — A response to a received BSR. You have the option to FIX an incomplete image that has been received by another station.

Forward error correction (FEC) — Forward error correction, an error-control technique in which the transmitted data is sufficiently redundant to permit the receiving station to correct some errors.

LeadIn — The number of redundant segments sent at the beginning of the DRM file transmission to allow the receiving station to become synchronized.

Main service channel (MSC) — Contains the data. Can be modulated in 4-QAM, 16-QAM, or 64-QAM.

Mode — In digital SSTV, a particular submode of a DRM transmission. The amount of data in each segment is determined by the submode selected. Robustness varies for each submode.

QAM — Quadrature Amplitude Modulation. A method of simultaneous phase and amplitude modulation. The number that precedes it, for example 64-QAM, indicates the number of discrete stages in each pulse.

Reed-Solomon error correction — A data encoding process that inserts redundant data so that errors in reading the data may be detected and corrected. *EasyPal* software provides four levels ranging from Very Light Encode (RS1) to Heavy Encode (RS4).

Resolution — The resolution of an image is the detail of that picture. Higher resolutions result in large image sizes and therefore take longer to transmit but will result in a received image having greater detail.

RS files — These are encoded files using the Reed Solomon encode/decode protocol.

Segment — A portion of the transmitted image. Many segments make up the total image. Bad segments can be re-sent faster than resending the total image. It contains file name or transport ID and data.

Thumbnail — This is a miniature view of an image.

TUNE — In DRM, a three-tone transmission used to set levels, check for IMD and adjust frequency.

11 Bibliography and References

ATV

Andrews. J., KH6HTV, "ATV Application Notes," **kh6htv.com/application-notes**. (A collection of 60 application notes covering all aspects of both analog and digital ATV.)

Andrews, J., KH6HTV, "Digital ATV Repeaters," *QST*, Sep. 2019, pp. 40 – 41.

Andrews. J., KH6HTV, "DVB-T: A Solution for ARES Television Operations," *QST*, June 2015, pp. 42 – 44.

Andrews, J., KH6HTV, "Microwave Amateur Television," *QST*, Oct. 2021, pp. 58 – 59.

Andrews. J., KH6HTV, "Modern ATV System Design," *QST*, Feb. 2013, pp. 46 – 47.

ATV Research website, **www.atvresearch.com** (cameras, cable TV modulators and cameras).

"ATV Handbook – an Introduction to Amateur TV." AN-55a, Feb. 2021.

ATV Research website, **www.atvresearch.com** (cameras, cable TV modulators and cameras).

"Boulder, CO - DTV/ATV Repeater Coverage," AN-32, Sep. 2016.

Cerwin, S., WA5FRF, "Amateur Television from Model Planes and Rockets," *QST*, Sep. 2000, pp. 41 – 44.

CQ-TV, published by the British ATV Club, **www.batc.org.uk**.

"Field Trials Comparing VUSB, FM, DVB-S & 64-QAM Television," AN-3a, Sep. 2011.

"Introduction to Amateur Digital Television," AN-45, Aug. 2018.

Fischer, W., *Digital Video and Audio Broadcasting Technology — A Practical Engineering Guide*, 4th edition, (Springer 2020).

HAMTV website, **www.hamtv.com** (All about ATV by Tom O'Hara W6ORG).

Hi-Des website, **www.hides.com.tw** (Supplier of DVB-T ham modulators and receivers).

KH6HTV Video website, **www.kh6htv.com** (supplier of ATV products and many app notes).

Putman, P., KT2B, "Digital Television: Bigger, Wider, Sharper," *QST*, Aug. 2000, pp. 38 – 41.

O'Hara, T., W6ORG, "Ham TV Applications Notes," **hamtv.com/info.html**. (A collection of 23 analog ATV application notes.)

Ruh, H., "ATV Secrets for the Aspiring ATVer," Vol. 1 and Vol. 2. Available through *Amateur Television Quarterly* magazine.

Seiler, T., HB9JNX/AE4WA, et al., "Digital Amateur TeleVision (D-ATV), proc. ARRL/TAPR Digital Communications Conference, **atv.hamradio.si/pdf/datv.pdf**.

Shadbolt, M., WØKYQ, ATCO website **www.atco.tv** with many app notes on DVB-S ATV.

Sparano, D., "What Exactly Is 8-VSB Anyway?" **pdfs.semanticscholar.org/c91d/**.

SSTV BIBLIOGRAPHY AND REFRENCES

Bruchanov, M., OK2MNM, *Image Communications on Short Waves*, **www.sstv-handbook.com**.

Ely, R., WL7LP, MMSSTV.CHM, a Help file included with MMSSTV software.

Lanza, C., HB9TLK, "DRM Mode 'HAM' Specification."

Macdonald, C., VY2CM, "The Early Days of Amateur Radio Slow-Scan TV," **www.wisdompage.com/EarlySSTV.html**.

Mori, M., JE3HHT, MMSSTV.TXT, a Help file included with MMSSTV software.

Peterson, L., WA9TT, "SSTV Reports Using the P Scale," *CQ* magazine, Jan. 2017, pp. 76 – 79.

Taggart, R., "An Introduction to Amateur Television," *QST*, Part 1, Apr. 1993; Part 2, May 1993; Part 3, June 1993.

Taggart, R., WB8DQT, "Digital Slow-Scan Television," *QST*, Feb. 2004, pp. 47 – 51.

Taggart, R., WB8DQT, *Image Communications Handbook* (ARRL, 2002). **www.qsl.net/kb4yz**.