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.

The first part of this chapter, by Tom O'Hara, W6ORG, describes fast-scan television (FSTV), also called simply amateur television (ATV). ATV is full-motion video over the air, similar to what you see on your broadcast TV. Because of the wide bandwidth required for ATV signals, operation takes place on the UHF and microwave bands.

The second part of this chapter, prepared by Dave Jones, KB4YZ, describes slow-scan television (SSTV). Instead of full motion video, SSTV involves pictures that are transmitted at 8 seconds or longer per frame. SSTV is a narrow bandwidth image mode that is popular on the HF bands using SSB voice transceivers. SSTV operation can take place on FM, repeaters and satellites too. In previous editions, this material formed Chapter 32. Unless otherwise noted, references to other chapters refer to chapters in the print version of the *ARRL Handbook.*

1 Fast-Scan Amateur Television Overview

Fast-scan amateur television (FSTV or just ATV) is a wideband mode that is based on the analog *NTSC* (National Television System Committee) standards used for broadcast television in the US for many years, before most broadcasters switched to digital transmission in 2009. Analog AM and FM ATV use standard NTSC television scan rates. It is called "fast scan" only to differentiate it from slow-scan TV (SSTV) or digital TV (DTV). In fact, no scan conversions or encoders/decoders are necessary with analog ATV.

Any standard TV set capable of displaying analog NTSC broadcast or cable TV signals can display the AM Amateur Radio video and audio signals. New consumer digital television (DTV) sets sold in the US are designed to receive high definition television (HDTV) broadcasts using the 8-VSB (8-level Vestigial Side Band) standard from the Advanced Television Systems Committee (ATSC). DTV televisions will also include analog cable TV channel tuners until at least 2012. It is a good idea however, to not dispose of your old analog-only televisions, but keep them for ATV. Analog AM ATV on the 70 cm band will be the primary ATV system for some time.

To transmit ATV signals, standard RS-170 composite video (1-V peak-to-peak into 75 Ω) and line audio from home camcorders, cameras, DVD/VCRs or computers is fed directly into a transmitter designed for the ATV mode. The audio goes through a 4.5 MHz FM subcarrier generator in the ATV transmitter that is mixed with the video.

Picture quality is about equivalent to that of a VCR, depending on video signal level and any interfering carriers. All of the sync and signal-composition information is present in the composite-video output of modern cameras and camcorders. Most camcorders have an accessory cable or jacks that provide separate audio/video (A/V) outputs. Audio output may vary from one camera to the next, but usually it has been amplified from the built-in microphone to between 0.1 and 1 V P-P (into a 10-kΩ load).

1.1 ATV Activities

Amateurs regularly show themselves in the shack, zoom in on projects, show home video recordings, televise ham club meetings and share just about anything that can be shown live or by tape (see **Figs 1** and **2**, and application notes at **www.hamtv.com/info.html**). Whatever the camera "sees" and "hears" is faithfully transmitted, including full motion color and sound information. Computer graphics and video special effects are often transmitted to dazzle viewers. Several popular ATV applications are described in detail later in this chapter.

1.2 Comparing Analog AM, FM and Digital ATV

Receiving ATV using any of the three ATV modes is relatively easy using consumer televisions and receivers directly, or with the addition of an amateur band receive converter (downconverter). Much of the activity in an area depends on the first few hams who experiment with ATV, and on the cost and availability of equipment for others to see their first picture.

Analog AM TV on the 70 cm band is the easiest mode. The 70 cm ham band contains the same frequencies as cable channels 57 through 61, so a TV that has an analog cable tuner can be used for receiving ATV signals as well. Simple 70 cm ATV transmitters are available.

FM ATV also uses simple transmitters, but most activity is on the 13 cm and 23 cm

Fig 1 — Students enjoy using ATV to communicate school to school or between classrooms (top). The ATV view shows the aft end of the Space Shuttle cargo bay during a mission (bottom).

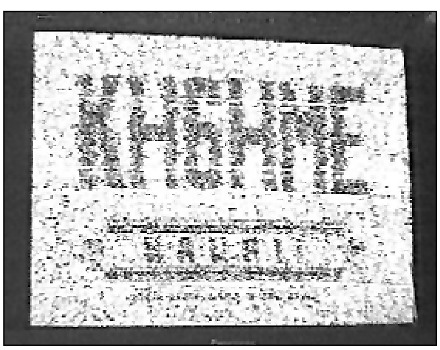


Fig 2 — The one-way ATV DX record is held by KC6CCC in San Clemente, California, for reception of 434-MHz video from KH6HME in Hawaii during a tropo opening in 1994. The distance is 2518 miles. See www.hamtv.com/atvdxrecord.html.

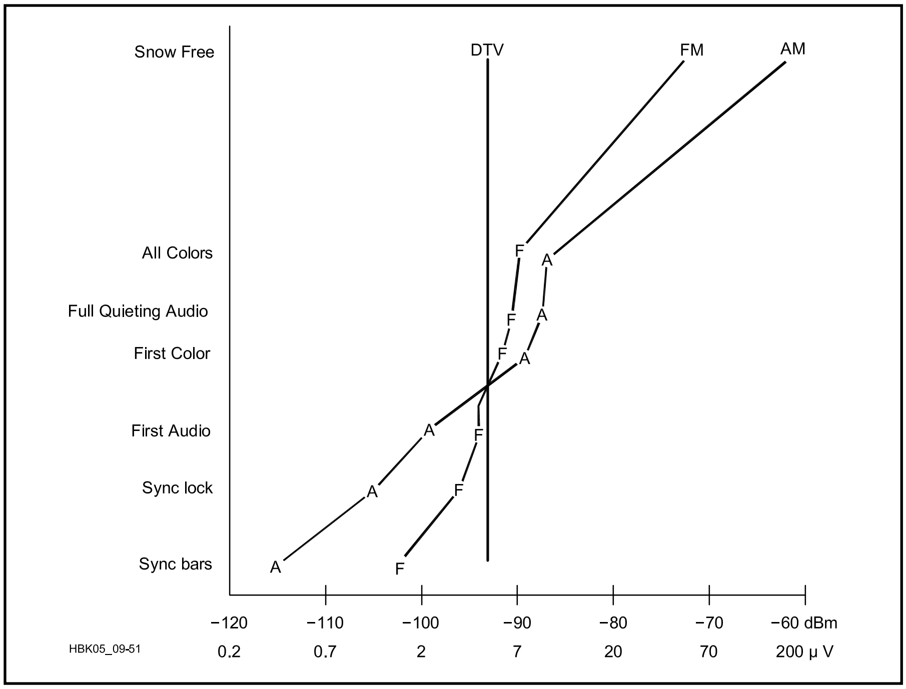


Fig 3 — Three approaches to ATV receiving. This chart compares AM, FM and digital ATV as seen on a TV receiver and monitor. Signal levels are into the same downconverter with sufficient gain to be at the noise floor. The FM receiver bandwidth is 17 MHz, using the US standard. The straight vertical line for DTV around –93 dBm illustrates the cliff effect described in the text.

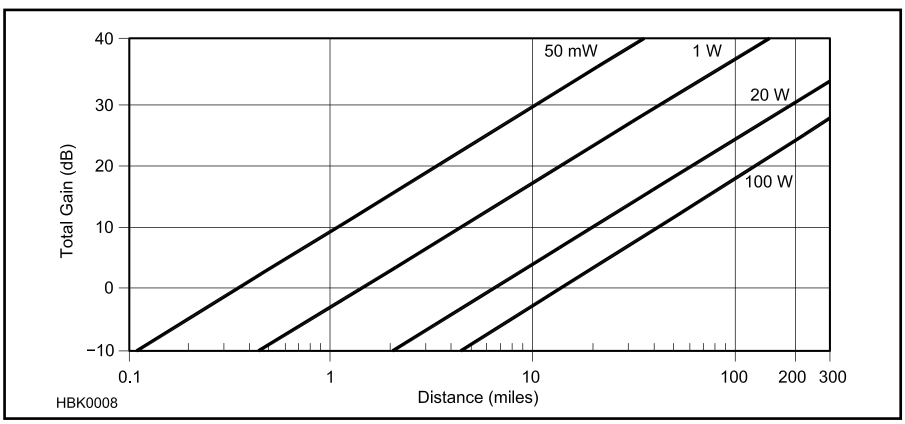


Fig 4 — This graph shows the possible line-of-sight distances for P5 (snow free) video reception for various analog AM ATV transmitter levels in the 70 cm band. Power levels shown are in PEP. The Total Gain is calculated by adding the antenna gain (dBd) for both the receive and transmit antennas and then subtracting the feed line loss (in dB) at both ends. For other bands: 33 cm, subtract 6 dB; 23 cm, subtract 9 dB; and 13 cm, subtract 15 dB. For FM ATV (4 MHz deviation, 5.5 MHz sound), add 12 dB. For ATSC 8-VSB digital TV, the sudden loss of picture "cliff effect" distance is found by adding 26 dB. If the noise figure of the first stage in the downconverter is greater than 2 dB, subtract for each dB over 2. See the example in Table 1.

amateur bands. This is in part because of the wide occupied bandwidth needed for FM ATV signals, and in part because of the availability of receivers originally designed for commercial satellite or license free Part 15 use. The FM receivers have analog A/V outputs that must be connected to a video monitor.

Digital ATV signals using 8-VSB can also be received simply by using new televisions in the same manner as analog cable televisions, but the transmitters are complex. Transmission requires an MPEG-2 compression and digital transport encoder and a digital RF modulator/exciter. 8-VSB is an amplitude-modulated, 8-level baseband signal that is processed and filtered to occupy 5.38 MHz bandwidth. This signal fits in a standard 6-MHz channel with guard bands. RF amplifiers for DTV are more critical as to drive level, linearity and low intermodulation distortion than with analog AM or FM ATV modes. A good reference on the technical characteristics of an ATSC 8-VSB transmission can be found in an article by David Sparano entitled "What Exactly Is 8-VSB Anyway?" and available online from **www.broadcast.net/~sbe1/8vsb/8vsb.htm**.

Table 1
ATV DX Graph Example

Transmit antenna	+10 dBd
Receive antenna	+12 dBd
Transmit feed line	–1 dB
Receive feed line	–2 dB
6 dB noise figure	–4 dB

Total Gain for 70 cm is 15 dB
With 20 W PEP, range is 35 miles (Fig 4)
For 23 cm (–9 dB) gain is 6 dB
With 1 W PEP, range is 3 miles (Fig 4)

PICTURE QUALITY

Experimentally, using the US standard, FM ATV gives increasingly better picture-to-noise (snow) ratios than AM analog ATV at receiver input signals greater than 5 µV. That's also about the signal level for the DTV "cliff effect" where the signal disappears. The DTV all-or-nothing cliff effect occurs because the digital signal detector and processing in the receiver requires a signal-to-noise ratio (SNR) of at least 15 dB for 8-VSB. Above 15 dB, you get an excellent picture, and at 14 dB SNR — nothing. Other DTV types — Digital Video Broadcast - Satellite (DVB-S) or Digital Video Broadcast - Terrestrial (DVB-T) — are a few dB better in the presence of noise.

Because of the wider noise bandwidth and FM threshold effect, AM analog video can be seen in the noise well before FM and DTV. For DX work, it has been shown that AM signals are recognizable in the snow at up to four times (12 dB) greater distance than FM or DTV signals, with all other factors equal. Above the FM threshold, however, FM rapidly overtakes AM. FM snow-free pictures occur above 50 µV, or four times farther away than with AM signals. The crossover point is near the signal level where sound and color begin to appear for all three systems. **Fig 3** compares analog AM, FM and digital ATV across a wide range of signal strengths.

1.3 How Far Does ATV Go?

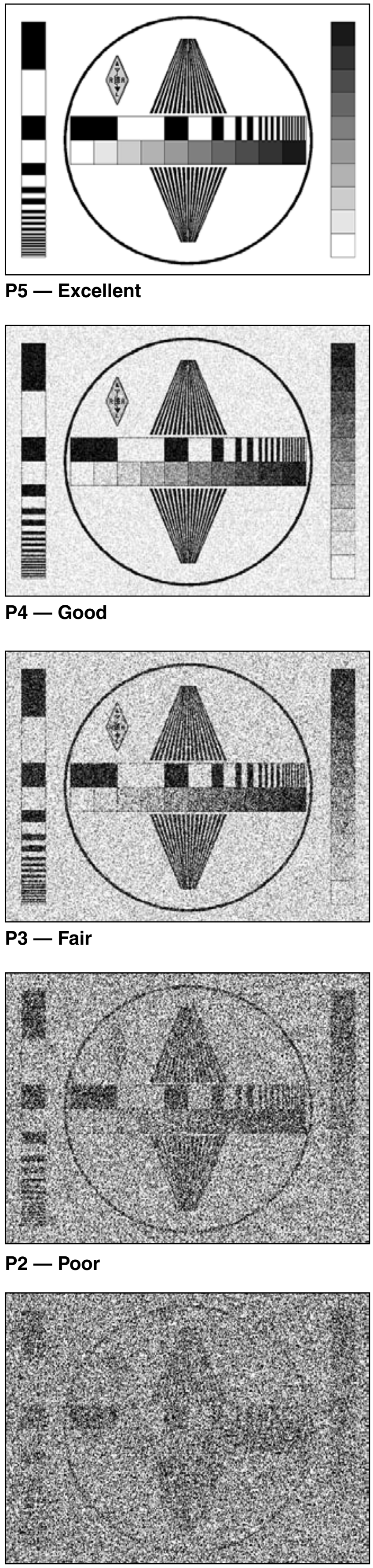
The theoretical snow-free line-of-sight distance for 20-W PEP 70 cm analog AM ATV, given 15.8-dBd gain antennas and 2 dB of feed line loss at both ends, is 150 miles. (See **Fig. 4**.) In practice, direct line-of-sight ATV contacts seldom exceed 25 miles. Longer distances are possible with over-the-RF-horizon tropo openings, reflections, or through high hilltop repeaters. A 2518-mile reception record is shown in Fig 2. (See the **Propagation of Radio Signals** chapter.)

The antenna system is the most important part of an ATV system because it affects both receive and transmit signal strength. For best DX, use low-loss feed line and a broadband high-gain antenna, up as high as possible.

A snow-free, or "P5," picture rating (see **Fig 5**) requires at least 200 µV (–61 dBm) of signal at the input of the analog AM ATV receiver, depending on the system noise figure and bandwidth. The noise floor increases with bandwidth. Once the receiver system gain and noise figure reaches this floor, no additional gain will increase sensitivity. At 3-MHz bandwidth the noise floor is 0.8 µV (–109 dBm) at standard temperature in a perfect receiver. Analog TV luminance bandwidth rolls off around 3 MHz to separate it from the color subcarrier at 3.58 MHz. If you compare this 3 MHz bandwidth to an FM voice receiver with 15 kHz bandwidth, there is a 23 dB difference in the noise floor.

Much like the ear of an experienced SSB or CW operator, however, the eye can pick out sync bars in the noise below the noise floor. Sync lock and large, well contrasted objects or lettering can be seen between 1 and 2 µV. Color and subcarrier sound come out of the noise between 2 and 8 µV depending on their injection level at the transmitter and characteristics of your TV set. For the ATV DXer, using an older analog TV that does not go to blue screen or go blank (like a video squelch) with weak signals is a must, especially when rotating the antenna for best signal.

Operators must take turns transmitting on the few available channels. Two meter FM is used to coordinate ATV contacts, and the 2 meter link allows full-duplex audio communication between many receiving stations and the ATV transmitting station speaking on the sound subcarrier. This is great for interactive show and tell. It is also much easier to monitor a squelched 2 meter channel using an omnidirectional antenna rather than searching out each station by rotating a beam. Depending on the third-harmonic relationship to the video on 70 cm, 144.34 MHz and 146.43 MHz (simplex) are the most popular frequencies. They are often mixed with the subcarrier sound on ATV repeater outputs so all can hear the talkback.



P5 — Excellent

P4 — Good

P3 — Fair

P2 — Poor

P1 — Barely perceptible

Fig 5 — An ATV quality reporting system.

2 Amateur TV Systems

Regardless of the type of ATV you're interested in — analog AM, FM or digital — you'll need to assemble the appropriate receiving and transmitting equipment and find other stations to work.

2.1 Analog AM ATV

Fig 6 shows the makeup of an analog AM TV channel (also called an NTSC channel) used for ATV, cable TV and for broadcast TV before the switch to digital. The channel is 6 MHz wide to accommodate the composite video, 3.58 MHz color subcarrier and 4.5 MHz sound subcarrier. Given the NTSC 525 horizontal line and 30 frames per second scan rates, the resulting horizontal resolution bandwidth is 80 lines per MHz. Therefore, with the typical TV set's 3-dB rolloff at 3 MHz (primarily in the IF filter), up to 240 vertical black lines can be seen. Color bandwidth in a TV set is less than this, resulting in up to 100 color lines. Lines of resolution are often confused with the number of horizontal scan lines per frame. The video quality should be every bit as good as on a home video recorder.

Most ATV is analog AM double sideband (DSB), with the widest component being the sound subcarrier out ±4.5 MHz. As can be seen in **Fig 7**, the video power density is down more than 30 dB at frequencies greater than 1 MHz from the carrier — more than 90% of the spectrum power is in the first 1 MHz on both sides of the carrier.

To fit within a 6 MHz wide channel, NTSC broadcast stations used an approach called vestigial sideband (VSB). VSB involves suppression, but not elimination, of the lower sideband so that it occupies less than 1 MHz. In addition, instead of combining a 4.5 MHz subcarrier to produce sound, broadcast stations used a second sound transmitter offset above the video carrier by 4.5 MHz so that the sound signal does not appear in the lower sideband.

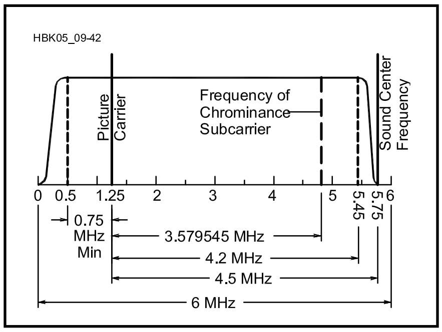


Fig 6 — An analog NTSC 6-MHz video channel with the video carrier 1.25 MHz up from the lower edge. The color subcarrier is at 3.58 MHz and the sound subcarrier at 4.5 MHz above the video carrier.

DSB and VSB are both compatible with analog cable TV tuners, but the lower sound and color subcarriers are rejected in the TV set IF filter as unnecessary. In the case of VSB, less than 5% of the lower sideband energy is attenuated. 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).

AM ATV FREQUENCIES

The lowest frequency amateur band wide enough to support an analog AM ATV channel is 70 cm (420-450 MHz), and it is the most popular. With transmit power, antenna gains and feed line losses equal, decreasing frequency increases communication range. The 33 cm (902-928 MHz) band goes half the distance that 70 cm does, but this can be made up to some extent with high-gain antennas, which are physically smaller at the higher frequency. Depending on local band plan options, there is room for no more than two simultaneous AM ATV channels in the 33 cm and 70 cm bands without interference. If there is an in-band ATV repeater, simplex ATV operation shares space with the repeater input. Before transmitting, check with local ATV operators, repeater owners and frequency coordinators listed in the *ARRL Repeater Directory* for the coordinated frequencies used in your area.

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 VSB filter characteristics. Cross-band ATV repeaters free up a channel on 70 cm for simplex and make it easier for repeater users to monitor their own repeated video with only proper antenna separation needed to prevent receiver desensitization.

Simplex, public service and R/C models use 426.25 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.

On the other hand, interference potential *to* ATV *from* other modes is high. Because a TV set receives a 6-MHz bandwidth, analog AM ATV is more susceptible to interference from many other sources than are narrower bandwidth modes. Interference 40 dB below the desired signal can be seen in video. Many of our UHF (and higher) amateur bands are shared with radar and other government radio positioning services. Signals from these services show up as horizontal bars in the picture. 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 put diagonal lines in the picture.

Other stations operating on narrowband modes more than 1 MHz above or below the video carrier rarely experience interference from an AM ATV signal, or even know that the ATV 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.

If the band is full and the lower sideband color and sound subcarrier frequencies need

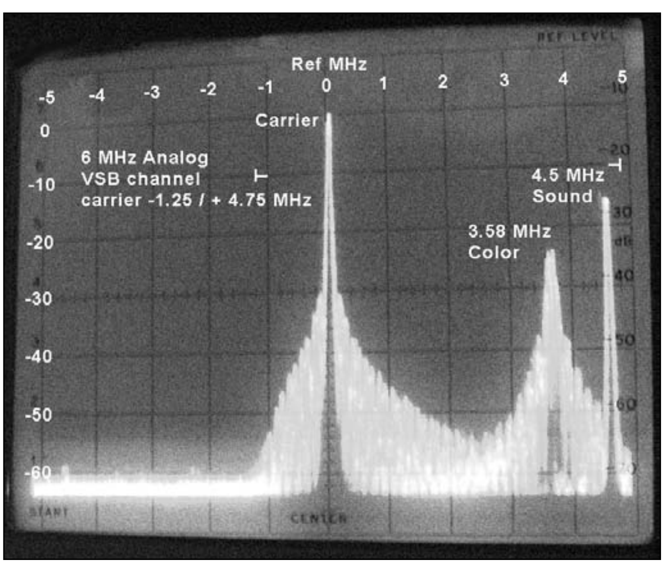


Fig 7 — Spectral display of a color analog AM VSB ATV signal. Spectrum power density varies with picture content, but typically 90% of the sideband power is within the first 1 MHz.

to be used by a dedicated link or repeater, a VSB filter in the antenna 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 most amateur linear amplifiers reinsert the lower sideband to within 10 dB of DSB, a VSB filter in the antenna line is the only cost-effective way to reduce the unnecessary lower sideband subcarrier energy if more than 1 W is used. 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.

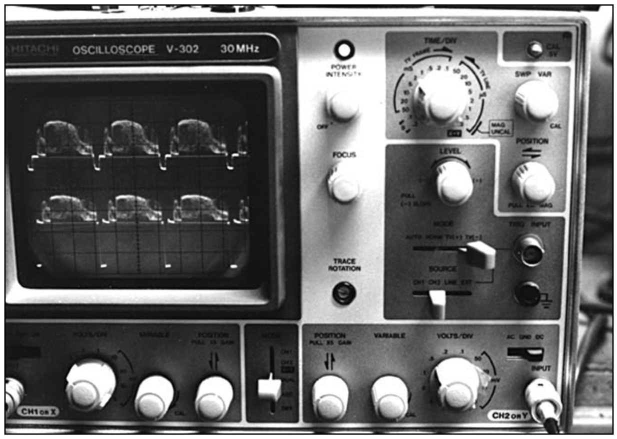


Fig 8 — An oscilloscope used to observe a video waveform. The lower trace is the video signal as it comes out of the sync stretcher. The upper trace is the detected RF signal from the amplifier.

RECEIVING AM 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. Cable channel 57 is 421.25 MHz, and each channel is progressively 6 MHz higher. (Note that analog cable channels and the old NTSC broadcast UHF channel frequencies are different above channel 13.) Check the *ARRL Repeater Directory* for a local ATV repeater output that falls on one of these cable channels. 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.

Most stations use a variable tuned downconverter specifically designed to convert the whole amateur band down to a VHF TV channel. Generally the 420 and 902 MHz bands are converted to TV channel 3 or 4, whichever is not used for over-the-air broadcast TV in the area. For 1240 MHz converters, channels 7 through 10 are used to get more 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.

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).

DRIVING AMPLIFIERS WITH AM ATV

Linear amplifiers for use with wideband AM video require some special design considerations compared to amplifiers used for FM and SSB voice operation. Many high-power amateur amplifiers would oscillate (and possibly self destruct) from high gain at low frequencies if feedback networks and power RF chokes did not protect them. These same stability techniques can affect operation over a 5-MHz video bandwidth. Sync, color and sound can be distorted unless the amplifier has been carefully designed for both stability and AM video modulation.

Several manufacturers offer special ATV amplifiers or standard models designed for all modes, including ATV. The collector and base bias supplies have a range of capacitors to keep the voltage constant under video modulation, while at the same time using the minimum-value low-resistance series inductors or chokes to prevent self-oscillation.

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 (see **Fig 8**).

To adjust a station with an ATV amplifier, disconnect both video and sound subcarrier and set the ATV transmitter's pedestal control for maximum power output. Then set the transmitter's RF power control to drive the amplifier to 90% of rated PEP output (this is the peak sync level). The 90% level is necessary to give some headroom for the 4.5 MHz sound subcarrier that is mixed and added with the video waveform. Once this peak sync level is set, use the blanking pedestal control to set amplifier output to 60% of this level. For example, a 100-W amplifier would first be set for 90 W with the RF power control and then 54 W with the pedestal control. Then the sound subcarrier can be turned back on and the video plugged in and video gain adjusted for best picture.

If you could measure RF output with a peak-reading power meter made for video, the power would be between 90 and 100 W PEP. A dc oscilloscope connected to an RF diode detector in the antenna line shows that the sync and blanking pedestal power levels remain constant at their set levels regardless of video gain setting or average picture contrast. On an averaging power meter, however, it is normal with video to read about half the amplifier's rated power. The power reading will actually decrease with increasing video gain or with a change to a predominantly white picture. An averaging RF power meter cannot give an accurate measurement for an AM video signal given so many variables. If the amplifier drive level is properly set up according to the procedure outlined above, the actual sync tip PEP will remain constant.

2.2 Frequency Modulated ATV

In Europe, FM ATV on the 23 cm (1240 MHz) band is the standard because there is little room for ATV in the amateur 70 cm band. In the US, AM on 70 cm remains the most popular ATV mode because of equipment availability, lower cost, less occupied bandwidth and use of a standard analog TV set for receiving. However, FM ATV is gaining interest among experimenters and repeater owners for links and alternate inputs.

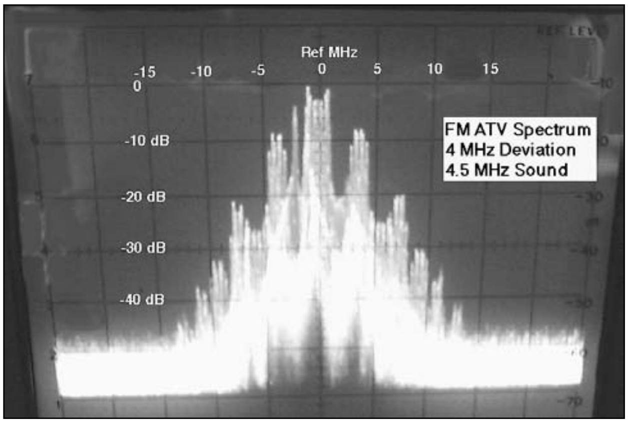


Fig 9 — Spectral display of an FM ATV transmission using 4 MHz deviation with a 4.5 MHz sound subcarrier. (Note that 5.5 MHz is the standard and would be 2 MHz wider.) Occupied bandwidth as defined in FCC Rule 97.3(a)(8) is –26 dB down from the mean power points.

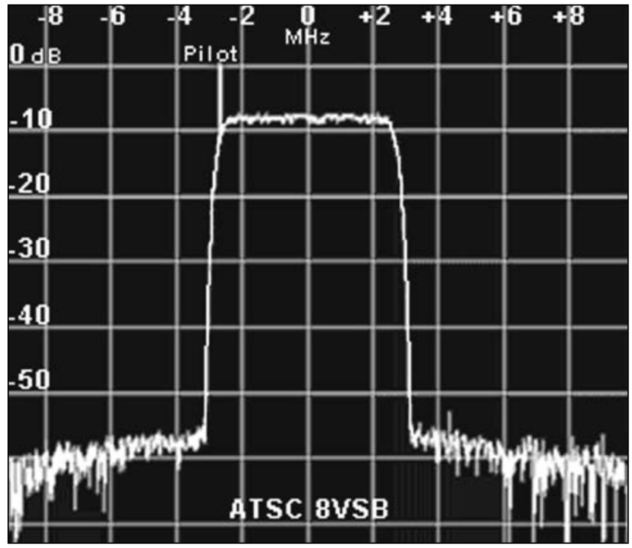


Fig 10 — Spectral display of an ATSC 8-VSB digital TV transmission. Note the pilot carrier unique to this mode of DTV.

As shown in **Fig 9**, FM ATV occupies 17 to 21 MHz depending on deviation and sound subcarrier frequency. While the 70 cm band is 30 MHz wide and thus theoretically could accommodate a 20 MHz wide FM ATV signal, the great interference potential to other users of the band precludes its use there. Most available FM ATV equipment is made for the 1.2, 2.4 and 10.25-GHz bands. The 3.3 and 5.6 GHz amateur bands are also being explored by using C-band satellite receivers and converted Part 15 equipment.

The US standard for FM ATV is 4 MHz deviation with the 5.5-MHz sound subcarrier set to 15 dB below the video level. Suggested frequencies are 1252 or 1255 MHz to stay away from FM voice repeaters and other users higher in the band, while keeping sidebands above the 1240 MHz band edge. Using the US standard, with Carson's rule for FM occupied bandwidth (see the **Modulation** chapter), it comes out to just under 20 MHz — so 1250 MHz would be the lowest possible frequency. Check with local frequency coordinators before transmitting because the band plan permits other modes in that segment.

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 cm 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-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.

Some of the inexpensive Part 15 wireless video receivers in the 33 cm band use 4-MHz deviation FM video. Most of the 2.4-GHz Part 15 units are FM, so they can be used directly. On 2.4 GHz, some of the Part 15 frequencies are outside the ham band and care should be taken to use only those frequencies at least 8 MHz inside the 2390-2450 MHz ham band.

Part 15 receivers may or may not have the standard de-emphasis video network, however, so some circuitry may have to be added. Video pre-emphasis in the transmitter and de-emphasis in the receiver can double the communication distance or give 6 dB of SNR improvement by reducing the receiver noise bandwidth. Coordination among local stations is needed, though, because you cannot match stations that have the networks with those that don't without distorting the video greatly.

2.3 Digital ATV

The greatest advantage to running digital ATV is that you have a perfect P5 picture all the way down to 15 dB above the noise floor, and higher definition is possible in the same 6 MHz channel width used for analog AM ATV (see **Fig 10**). If you use the signal-to-noise level required to have snow-free ATV as a reference, 8-VSB DTV is 20 dB better than the 4 MHz deviation FM ATV and 32 dB better than analog AM ATV. This is a significant consideration for long-distance, point-to-point, line-of-sight paths and for paths requiring wide fade margins.

DTV can send much more usable picture and sound information in the same bandwidth as analog AM ATV under the theory that you don't have to send a continuous serial stream of a scanned picture at 30 interlaced frames per second. Rather, in DTV you send one whole frame and then send frames of only the changed pixels (or those pixels predicted to change, as explained in the next paragraph). Just the changes are sent a specified number of times (usually up to 15 times) before starting over again with a new complete frame.

There are complex algorithms based on how the human eye and mind perceive the picture. For instance, there is the probability that a pixel or group of pixels that are moving in a direction on the screen will occupy the adjacent pixel location at a certain time. According to Henry Ruh, AA9XW (a longtime ATVer and Chief Engineer at WYIN TV in Chicago), the coder/decoder (codec) software may expect a moving pool ball to continue in a straight line. If you watch closely, however, you may see the ball go deeper into the cushion than it really did until the next full frame. The bottom line is that the picture you see may be 10% actual data and 90% predictions.

DIGITAL ATV TRANSMITTER REQUIREMENTS

As can be seen in Fig 10, in an 8-VSB signal there is a pilot carrier 310 kHz up from the lower channel edge generated by a dc offset of the eight level modulation. The pilot carrier has a tight tolerance of 3 Hz and gives the RF PLL circuits in the 8-VSB receivers something to lock onto that is independent of the data being transmitted. Unlike 8-VSB, DVB-T or DVB-S signals do not have a pilot carrier (see **Fig 11**).

DTV transmissions are rated at average power. With 8-VSB modulation, the peak power is 7 dB greater than the average, or about 5 times. DTV transmission requires an amplifier with high linearity and good IMD performance to prevent distortion, noise and spectrum sideband growth. For proper opera-

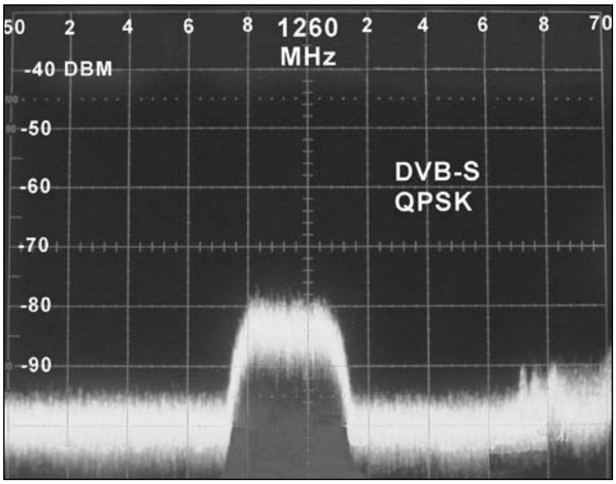


Fig 11 — A DVB-S signal from the WR8ATV repeater output as received on a spectrum analyzer. Note that the average power appears to be not too far above the noise floor, but gives a P5 picture. P units are measures of picture quality from P1 to P5 with P5 being the clearest and best picture.

Fig 12 — Art Towslee, WA8RMC, in his shack transmitting DTV through the local ATV repeater in Columbus, Ohio.

tion, amplifiers for 8-VSB operation are run at average powers that are 20% of their rated 1 dB gain compression levels. For example, an amplifier you might run at 100 W PEP output with analog AM ATV would run at 20 W average power or less for 8-VSB DTV. With DVB-T and DVB-S, power output can run slightly higher — up to 33% of an amplifier's rated 1 dB gain-compression level. Lower transmit power levels are not an issue, though. As described earlier, DTV requires less signal strength than analog AM ATV to produce a P5 picture.

With DTV, it's not a good idea to follow the amateur tradition of increasing amplifier drive to the point that a receiver starts to break up and then back the drive down a little. Although increased transmitter IMD may not affect the received signal until the combination of the received signal-to-noise and the added transmitter amplifier noise reaches the 15 dB cliff, the generated sideband levels can be quite large and interfere with other users.

An analog VSB filter in the antenna line can help keep the unwanted sideband growth down. As can be seen in Fig 10, DTV spectrum power density is high across the whole channel width and will show up as noise in a narrowband receiver tuned within the 6 MHz channel. For this reason, DTV should be used in the higher bands or 420-431 MHz segment of the 70 cm band so as not to interfere with FM voice repeaters, weak signal modes and satellite work.

DTV ISSUES

DTV using 8-VSB will stop working or freeze-frame with just a few miles per hour of antenna movement or multipath ghosting. Unlike analog ATV, DTV is impractical for mobile, portable, R/C vehicles and balloons. Developments in technology may allow mobile reception of over-the-air 8-VSB broadcast in the future. DVB-T does not have this problem, but is much more complicated and expensive to generate. DVB-S has some multipath susceptibility, but tests in Europe and the US show that it performs well under mobile conditions. Over time, DVB-S will likely become the most widely adopted amateur DTV system in the US, especially with the availability of inexpensive "free to air" satellite receivers.

Another unique factor with DTV communication is getting used to the digital processing delay when using a 2 meter talkback channel or even duplex audio and video. The delay can vary from a few hundred milliseconds to seconds.

AMATEUR DTV SYSTEMS

The first amateur DTV repeater in the US is in Columbus, Ohio (see **www.atco.tv**). This repeater uses DVB-S with QPSK modulation on 1260 MHz. Art Towslee, WA8RMC (shown in **Fig 12**) has a good simplified explanation of the various DVB modes on the ATCO Digital TV News Web page.

Nick Sayer, N6QQQ, has a blog in which he describes his experiments with 8-VSB on 33 cm — **nsayer.blogspot.com/search/label/ham**.

Early work by Uwe Kraus, DJ8DW and others is described at **www.von-info.ch/hb9afo/histoire/news043.htm**. Their experiments date to 1998, when they were the first to transmit moving color pictures with sound via a digital amateur television link over a distance of 62 miles. The early work used a 2 MHz bandwidth on 70 cm with 15 W output and 15 dB gain antennas.

Also see **www.von-info.ch/hb9afo/datv_e.htm** for sources and descriptions of DTV encoder and exciter boards. Most of these will take in a video signal and two audio signals and output a few milliwatts on an IF frequency to be mixed up to a ham band. The signal may also have a specific ham band output. Some have jumpers to select QPSK, GMSK, QAM or 8-VSB modulation as well as various forward error correction (FEC) and symbol rates.

With the shift to broadcast DTV in the US, it's possible that consumer RF modulators will start appearing for connecting video devices to TVs. This will bring the size and cost of chip sets down and make experimentation with 8-VSB and other DTV modes more economically practical for amateurs.

For more technical information on MPEG-2 compression see **en.wikipedia.org/wiki/MPEG-2**.

2.4 ATV Antennas

Foliage greatly attenuates signals at UHF, so place antennas above the treetops for the best results. Beams made for 432 MHz SSB/CW work or 440 MHz FM may not have enough SWR bandwidth to cover all the ATV frequencies for transmitting, but they are okay for reception. A number of manufacturers make beam antennas designed for ATV use that cover the whole band from 420 to 450 MHz. Use low-loss feed line and weatherproof all outside connectors with tape or coax sealer. Almost all ATV antennas use N connectors, which are more resistant to moisture contamination than other types. See the **Transmission Lines** and **Component Data and References** chapters for help with appropriate cable and connectors.

Antenna polarization varies from area

(A)

(B)

Fig 13 — At A, the simplest video identifier is to draw your call sign on a piece of paper and put it on the wall of your ham shack and in view of the camera. Doug Moon, K6KMN, also has his old auto call letter license plate as his ID. At B, the call sign, event name and location are overlaid on the video. During a public service event such as a long trail running race it is easy to forget to ID especially if operating full duplex and a lot is going on. See www.foothillflyers.org/hamtvac100.html for a description of ATV at the Angeles Crest 100 Mile Trail Race.

to area. It is common to find that the polarization was determined by the first local ATV operators based on antennas they had in place for other modes. Generally, UHF/microwave operators active on SSB, CW and digital modes have horizontally polarized antennas, while those into FM, public service or repeaters have vertical antennas. Check with local ATV operators before permanently locking down the antenna clamps. Circularly polarized antennas let you work all modes, including satellites.

2.5 ATV Identification

ATV identification can be on video or the sound subcarrier. A large high-contrast call-letter sign on the wall behind the operating table in view of the camera is the easiest way to fulfill the requirement (see **Fig 13A**). Transmitting stations fishing for DX during band openings often make up call sign IDs using fat black letters on a white background to show up best in the snow. Their city and 2 meter monitoring frequency (typically 144.34 or 146.43 MHz) are included at the bottom of the sign to make beam alignment and contact confirmation easier.

Quite often the transmission time exceeds 10 minutes, especially when transmitting demonstrations, public service events, space shuttle video, balloon flights or videotape. Intuitive Circuits makes a variety of boards that will overlay text on any video looped through them. Call sign characters and other information can be programmed into the board's nonvolatile memory by on-board push buttons or an RS-232 line from a computer (depending on the version and model of the board). See Fig 13B.

One model will accept NMEA-0183 standard data from a GPS receiver and overlay latitude, longitude, altitude, direction and speed, as well as call letters, on the applied camera video. This is ideal for ATV rockets, balloons and R/C vehicles. The overlaid ID can be selected to be on, off or flashed on for a few seconds every 10 minutes to automatically satisfy the FCC ID requirement. The PC Electronics VOR-3 video operated relay board has an automatic nine-minute timer, and it also has an end-of-transmission hang timer that switches to another video source for ID.

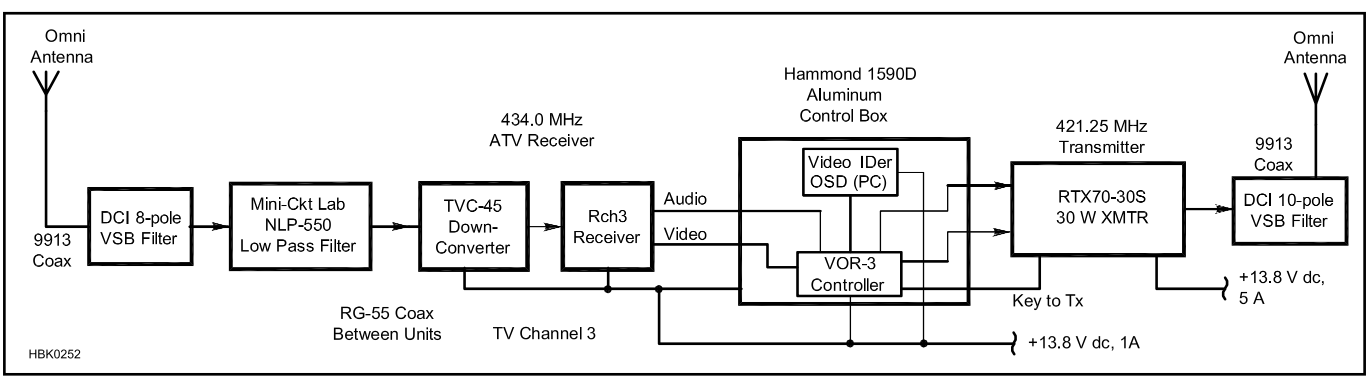


Fig 14 — A block diagram of a 70 cm in-band ATV repeater. The omnidirectional antennas are vertical and require 20 ft (minimum) of vertical separation to get >50 dB isolation to prevent receiver desensitization. Horizontal omnidirectional antennas require much more separation. A low pass filter on the receiver is also necessary because VSB or cavity type filters repeat a pass-band at odd harmonics and the third-harmonic energy from the transmitter may not be attenuated enough. P. C. Electronics makes the receiver, transmitter and VOR. Video ID can be done with a video overlay board like the Intuitive Circuits model OSD(PC) — by itself or even overlaid on a tower cam. Alternatively, an Intuitive Circuits ATVC-4+ ATV repeater controller board can do all the control box functions as well as remotely select from up to four video sources.

2.6 ATV Repeaters

There are two kinds of ATV repeaters: in-band and cross-band. In-band repeaters for 70 cm are more difficult to build and use, yet they are more popular because equipment for that band is more available and less expensive. Many ATV repeaters have added streaming video of their outputs to the Internet so users can see when they are active. Some repeaters even use the Internet to establish links. A good number of US repeaters can be found on the **www.batc.tv** Streaming Members Web site.

Why are 70 cm ATV repeaters more difficult to build than voice repeaters? The wide bandwidth of ATV makes for special filter requirements. Response across the 6-MHz passband must be as flat as possible with minimum insertion loss, but response must sharply roll off to reject other users as close as 12 MHz away. Special 6 to 10 pole interdigital or combline VSB filters are used to meet the requirement. An ATV duplexer can be used to feed one broadband omnidirectional antenna, but an additional VSB filter is needed in the transmitter line for sufficient attenuation to keep noise and IMD product energy from desensing the receiver.

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 cm and 33 cm bands.

Fig 15 — ATV repeater "tower cam" IDs have become popular so that users can see approaching weather. Some cameras have remote pan and tilt, so users can observe ice build-up on antennas or activity at the repeater site.

A 70 CM ATV REPEATER

Fig 14 shows a block diagram for a simple 70 cm in-band analog AM ATV repeater. No duplexer is shown because the antenna separation (>50 dB) and VSB filters provide adequate isolation.

To prevent unwanted key up from other signal sources, ATV repeaters use a video operated relay (VOR). The VOR senses the horizontal sync at 15,734 Hz in much the same manner that FM repeaters use CTCSS tones. Just as in voice repeaters, an ID timer monitors VOR activity and starts the repeater video ID generator every nine minutes, or a few seconds after a user stops transmitting.

A tower-mounted camera is often used in place of a video ID generator at repeaters (see **Fig 15**).

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.

3 ATV Applications

3.1 Public Service

Video from an incident site back to an Emergency Operations Center (EOC) is a valuable addition to disaster communications. A real-time view of the incident scene can give commanders an immediate feel for the overall picture of what is going on or zoom in on a critical component rather than rely solely on descriptions relayed by voice or data. ATV has the added benefit of full duplex audio. The ATV transmitting station in the field talks on the sound subcarrier and the EOC can talk back at the same time on 2 meter FM voice. A camera and transmitter can be put on a robot and sent into a hazardous situation with no risk to people.

AN ATV "GO KIT"

Communications "Go-Kits" are popular with ARES and RACES groups. When an

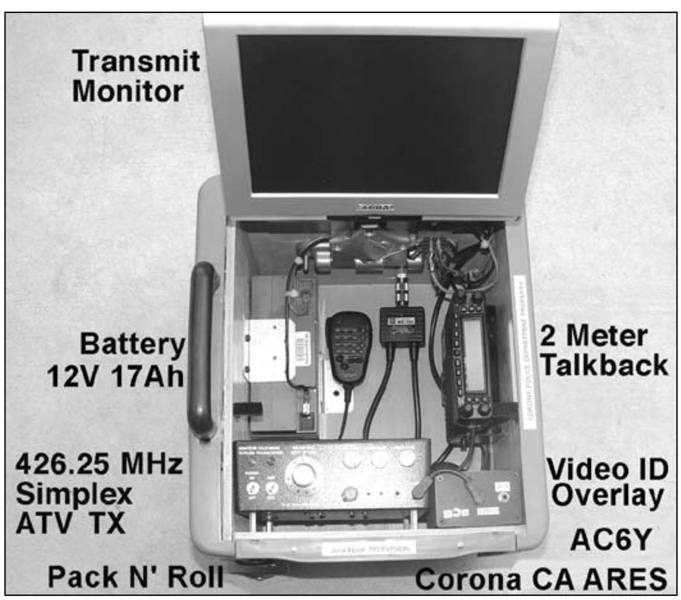


Fig 16—This portable ATV Go-Kit for emergency and public service work was built by Nick Klos, AC6Y. It includes a 70 cm ATV transmitter, 2 meter FM transceiver and battery in a Pack N' Roll container.

emergency occurs, hams can just grab their kit and go out in the field with everything they need. Nick Klos, AC6Y, put together three ATV Go-Kits for the police department ARES group in Corona, California. See **Fig 16**. Each kit uses an easy-to-transport Pack-N-Roll enclosure. (Pack-N-Rolls come in various sizes, have wheels, and have an extendable handle similar to airline carry-on luggage.) The ATV transmitter, 2 meter transceiver, battery and optional video monitor are fastened to plywood 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 ft 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.

PORTABLE REPEATERS

A portable ATV repeater for public service events can also be built in a Pack-N-Roll 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.

The portable repeater shown in **Fig 17** is a cross-band unit with 70 cm input and 23 cm output. By using 70 cm input to the repeater, you get 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 because you don't have to contend with strong repeater transmitter harmonics in the receiver. Antenna separation of 5 ft is usually enough running a low-power, low-in/high-out portable repeater.

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 desense. 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.

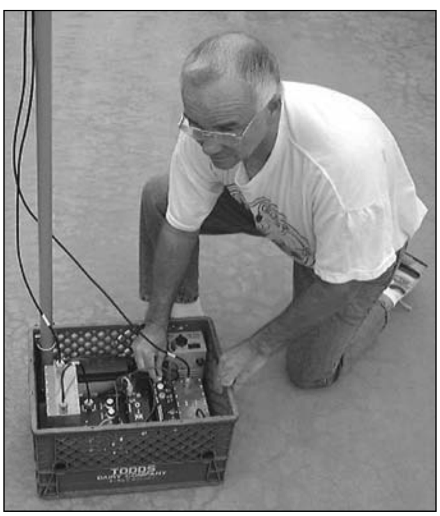
With compact 10-dBd gain corner reflectors or higher gain beams on 23 cm, you can get more than 5 miles line-of-sight from the repeater to the EOC with just 3 W of transmitter power. The portable repeater shown is self-contained with a 12-V, 17-Ah battery that will last about 12 hours. Alternatives include ac-operated 13.8 V, 3 A power supply or a dc cord clipped to a car battery. A local camera can be plugged in and used if needed. Details of the milk crate repeater can be found at **www.hamtv.com/info.html** under Portable Public Service Repeater.

3.2 Radio Control Vehicles

Some hams also enjoy operating radio control (R/C) vehicles, and ATV can add a new dimension to that hobby. The size, weight and cost of color cameras have come way down, and ATV transmitters are smaller as well, so ATV stations can more easily be integrated into R/C vehicles to give them eyes and in some cases ears.

AN EDUCATIONAL TOOL

Mark Spenser, WA8SME (ARRL Amateur Radio Education and Technology Coordinator) added ATV capability to a Parallax Board of Education Robot (BOE/BOT) as shown in **Fig 18**. With the add-on ATV board, the BOE/BOT simulates a Mars Lander. The robot and ATV board are also used to teach students how a TV remote control works, as well as demonstrate remote sensing and



(A)

(B)

(C)

Fig 17 — At A, Tom O'Hara, W6ORG, adjusts a portable ATV repeater for public service work that can be built in a milk crate. The block diagram is similar to Fig 14 but without the VSB filters. The transmitter is a P. C. Electronics RTX23-3 on 1253.25 MHz, the receiver is on 426.25 MHz, and small beams or omni antennas are used. For more details on construction, visit www.hamtv.com. At B, the repeater is flown to a hilltop and quickly set up. Sharon Kelly, KF6OQO, is adjusting the antenna. At C, the video of a fire can be seen at an EOC on the other side of the hill while Gary Heston, W6KVC, talks back to the incident site ATV operator on 2 meters.

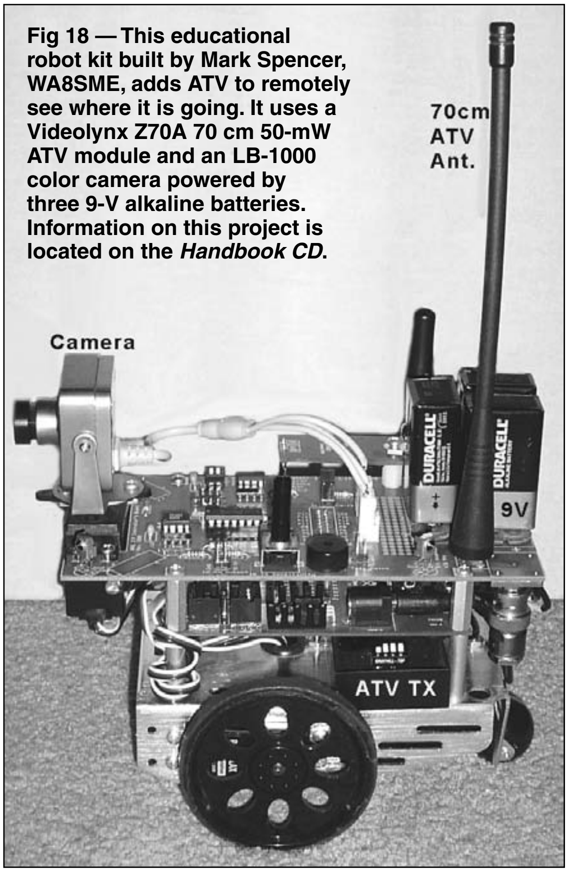


Fig 18 — This educational robot kit built by Mark Spencer, WA8SME, adds ATV to remotely see where it is going. It uses a Videolynx Z70A 70 cm 50-mW ATV module and an LB-1000 color camera powered by three 9-V alkaline batteries. Information on this project is located on the *Handbook CD*.

data linking. This ATV application has encouraged students to use the kit as a science class project and become licensed hams in the process.

R/C VEHICLE TIPS

ATV and data transmitter modules have been put in R/C aircraft, blimps, cars and boats. A 50 mW transmitter on 70 cm is enough to give good video for ½ mile or so around an R/C flying field. An inverted ground-plane or vertical dipole is used typically on aircraft, but nulls in the radiation pattern can show up at steep bank angles. Ground-plane antennas are also used for receive because the pattern is broad. Mounting the receive antenna at least 10 ft above ground can help avoid multipath ghosting or signal blockage from nearby people and vehicles. Use of higher gain omnidirectional antennas is tempting for greater distance, but they have narrower radiation patterns and more nulls.

Operation at higher frequencies requires shorter antenna lengths that better might fit the physical size limitations of an R/C vehicle, but snow-free distance will be shorter given the same transmitter power and receive antenna gains.

If ac power is not available at the flying field for plugging in a TV, look for a portable television that can be powered from batteries. Some hams have used TV tuners designed for use with laptop computers. Position the screen to be north facing for least sun washout. It is best for even experienced R/C operators to not fly solely by video, but to have a copilot observe directly as the camera's field of view is limited.

Typical 72 MHz or 50 MHz R/C receivers are not designed to operate with a transmitter in the same vehicle. The R/C receiver front end could overload from ATV transmitter RF, so control distance testing is a must before the first flight. Testing can be done by having another ham (with a handheld radio for talkback) carry the R/C vehicle out to the normal limit of control distance. Then turn on the R/C transmitter and verify that the controls are working normally. Finally, turn on the ATV transmitter and again verify operation.

If the R/C receiver is captured by the ATV transmitter, then experiment with lowering power, changing antenna placement, or adding shielding or filtering. In the past, crystal oscillator leakage was often the culprit, rather than the 70 cm output. Shielding cured that. Interference may be less of a problem with a newer ATV transmitter that uses a PLL oscillator.

A PRACTICAL EXAMPLE

The added weight of the ATV system on the electric R/C helicopter shown in **Fig 19** is only 7 oz, but first you need to determine that the craft can lift the added load. The extra equipment must be mounted to maintain balance around the aircraft's center of gravity. Some testing with equivalent weights first can save equipment from possible damage. Note the stubby flexible antenna mounted upside down on one of the skid supports. This is counterbalanced by mounting the R/C receiving antenna on the opposite side.

A separate battery should be used for the ATV system rather than tapping into the motor or R/C receiver battery. The voltage will vary during the flight and could put motor noise in the video. A standard 9 V alkaline battery will last almost two hours continuous

(A)

(B)

Fig 19 — At A, cable ties are used to fasten an LB-1000 color camera, Videolynx 434 ATV transmitter, 9-V battery and Diamond RH3 antenna to an R/C helicopter powered by an electric motor. At B, a computer with a TV tuner plugged into the USB port is used to view video coming from the ATV transmitter on the R/C helicopter — in this case, looking back at the R/C model operator.

duty with this system.

On larger R/C aircraft having sufficient payload, a GPS receiver and Intuitive Circuits video overlay board can put the speed, altitude and direction, along with call sign, over the camera video.

3.3 ATV from Near Space

Seeing the earth fall away via ATV as an amateur rocket or balloon rises can be quite exciting as shown in **Fig 20**. There are a number of groups sending up balloons and rockets with instrumentation, beacons and repeaters in addition to ATV. Balloon transmissions have been received as far as 500 miles away as the instrument package rises to 100,000 ft before the balloon pops from gas expansion and then parachutes back to earth. Radio direction finding clubs are often asked to help find where the balloon has come down and aid in recovery.

Rockets and balloons using ATV present a challenging optimum antenna radiation pattern problem similar to satellites that are predominantly flown overhead. For strongest picture and best distance (DX), the transmit and receive antennas should have their major power lobes pointed at each other and use the same polarization.

An omnidirectional vertical dipole antenna in the vehicle is fine for best DX on the horizon where the receiving station views the vehicle from a low angle. For example if a rocket is expected to go 1 mile vertically, receiving stations at 4 miles or more away will be within the maximum radiation lobe of the antenna and get the best video. Receiving stations at the launch site or closer than 4 miles away would be within pattern nulls.

If the rocket antenna is a ¼ wave vertical spike on the nose and the body of the rocket is the ground plane, the main lobe can have an up-tilt of 15 to 20° above the horizon and a significant amount of the signal will be wasted. Balloons can use an upside down ground plane hanging below the instrument package to give a down tilt to the earth below.

At the launch site, a horizontal dipole on the rocket (see **Fig 21**) and circularly polarized antenna on the ground works best. Balloons do well by hanging down an omnidirectional wheel antenna that is horizontally polarized on the horizon, but circularly polarized directly below. Circular polarization at one end helps to minimize the signal strength variation as the vehicle spins.

A 1-W, 70 cm ATV transmitter board such as the P.C. Electronics TXA5-RC series is a good tradeoff between power and battery weight. A beam antenna for reception is necessary to make up for the low power if you want snow-free pictures from higher than 20,000 ft. Typically, ATV equipment is housed in an insulated enclosure suspended below the helium-filled balloon, along with a battery capable of lasting the expected length of flight time. Styrofoam is light and will retain some of the heat dissipated from the electronics so that the extreme cold at altitude does not cause the transmitter and battery to cease operation.

Balloon and rocket groups have a lot of how-to information and often announce when there will be a launch so that hams within a few hundred miles radius can try receiving the signals. Some groups are:

Bill Brown WB8ELK Balloon Flights — **fly.hiwaay.net/~bbrown**

Arizona Near Space Research ballooning — **www.ansr.org**

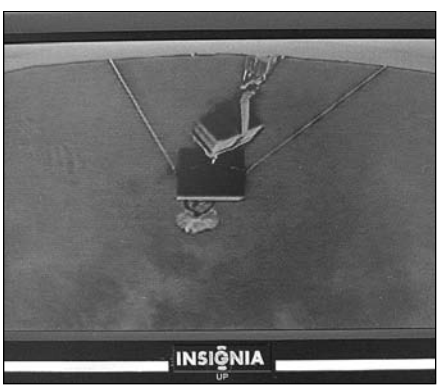
Amateur High Altitude Ballooning — **www.nearsys.com**

Edge of Space Science ballooning — **www.eoss.org**

N8UDK rocket ATV — **www.detroitatvrepeater.com/rockets.htm**

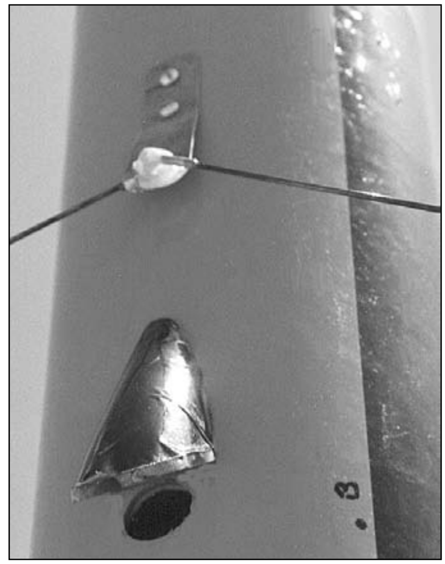
KC6CCC rocket ATV — **www.qsl.net/kc6ccc/rockets.htm**

(A)

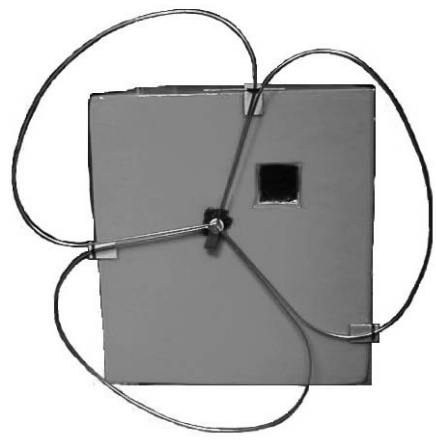


(B)

Fig 20 — At (A), an ATV camera view from a balloon at 93,399 ft shows the blackness of space, the curvature of the earth and hazy clouds below. Note that the standard NMEA altitude data output from GPS receivers is in meters. At (B), video received from a balloon on a 7-inch portable LCD TV at 20 miles slant distance. The camera is looking down at the instrument package, with clouds and the ocean below.



(A)



(B)

(C)

Fig 21 — At (A), a dipole antenna and a mirror are mounted on the outside of a 3.5-inch diameter amateur rocket. A video camera inside looks through the hole to the mirror so those receiving can see the view of the ground fall away as the rocket blasts off. At (B), N8UDK mounted an Old Antenna Lab 70 cm Little Wheel horizontal omni antenna to the bottom of his high-altitude balloon ATV payload. The camera is mounted inside the insulated foam package and looks out through the square cutout. At (C), a handheld antenna using circular polarization can be pointed at a balloon or rocket for maximum signal level as it travels. See www.hamtv.com/rocket.html.

4 Video Sources

Practically any video device that delivers a picture when plugged into the coaxial video jack of a video monitor can be plugged into an ATV transmitter and used to send video over the air. Suitable sources include the composite video from camcorders, video cameras, digital cameras, VCRs or computers. The standard A/V cable from a video device has a phono plug on the end and is often identified by yellow color coding (other colors are used for audio).

The cost of video cameras has come way down, thanks to the development of solid state imaging devices that vary in size, type and number of horizontal and vertical picture elements (pixels). Cameras widely available for home video work well for ATV.

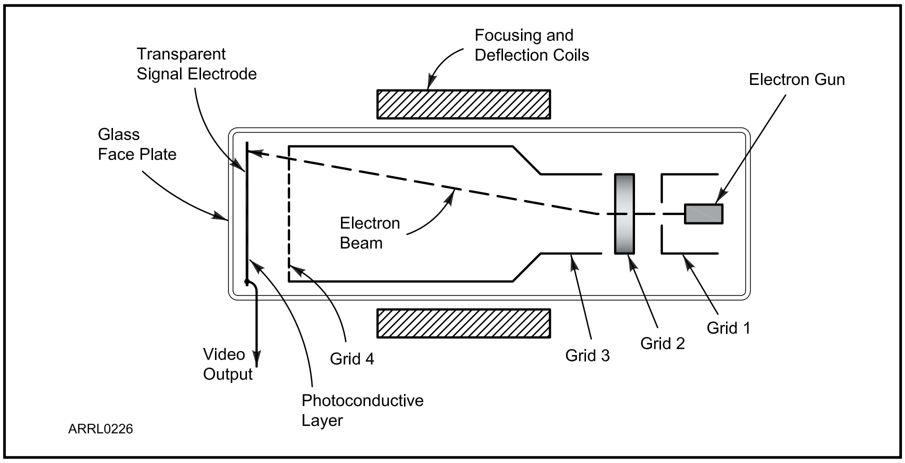


Fig 22 — The construction of a vidicon tube used for acquiring video images. Light striking the front of the tube causes the current in the electron beam from the cathode to photoconductive layer to change. These changes create the electronic video signal.

VIDICON TUBES

The vidicon is a relatively simple, inexpensive vacuum tube imaging device that once was the standard for home video cameras, closed-circuit television and ATV applications. **Fig 22** shows a vidicon's physical construction. As with a cathode ray tube (CRT), an electron beam is created by a cathode and accelerated by grids. Horizontal and vertical deflection of the electron beam in a vidicon is accomplished with magnetic fields generated by coils on the outside of the tube. Varying the strength of the fields control the beam's position as it scans across the inside of the front of the vidicon, which is coated with a photoconductive screen layer. As the electron beam scans the screen, it charges each spot on the screen to the cathode voltage (about –20 V with respect to the signal electrode). Each spot acts like a leaky capacitor, discharging when illuminated by light hitting the front of the vidicon. The rate of discharge depends on the intensity of light illuminating the spot.

When it next scans across the spot, the electron beam will deposit enough electrons to recharge the spot to cathode potential. As it does so, the current flowing between the cathode and the screen increases, proportionally to how much the spot's "capacitor" discharged since last being scanned by the beam. Since this discharge depends on the amount of light hitting that spot on the screen, the changes in the beam current as it scans the screen correspond to the image being viewed by the screen. This creates a video signal that represents the scanned image. The variations in the beam current are very low (a fraction of a microamp), and the output impedance of the vidicon is very high, so the video circuitry must be designed with care to minimize hum and noise and the tube itself must be carefully shielded.

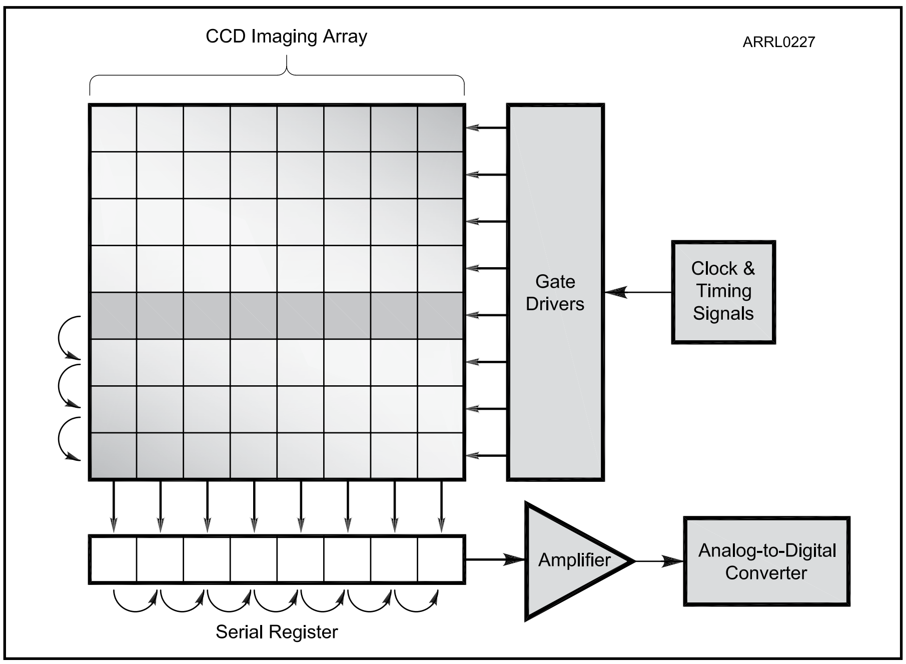


Fig 23 — The construction of a two dimensional CCD array that might be used in a digital camera. When a control pulse biases the array to conduct, the first row passes its sampled voltage on to the next row and takes another sample. With each successive control pulse, the input samples are passed to the next row until they reach the edge of the array. There they are transferred to a serial register and digitized.

CHARGE-COUPLED DEVICES

A *charge-coupled device (CCD)*, in its simplest form, is made from a string of small capacitors with a MOSFET on its input and output. The first capacitor in the string stores a sample of the input voltage. When a control pulse biases the MOSFETs to conduct, the first capacitor passes its sampled voltage on to the second capacitor and takes another sample. With each successive control pulse, the input samples are passed to the next capacitor in the string. When the MOSFETs are biased off, each capacitor stores its charge. This process is sometimes described as a "bucket brigade," because the analog signal is sampled and then passed in stages through the CCD to the output.

Fig 23 shows a two-dimensional CCD that might be used in a digital camera. In a CCD used for imaging, an array of sensing elements called *pixels* are coated with light-sensitive material. The light-sensitive mate-

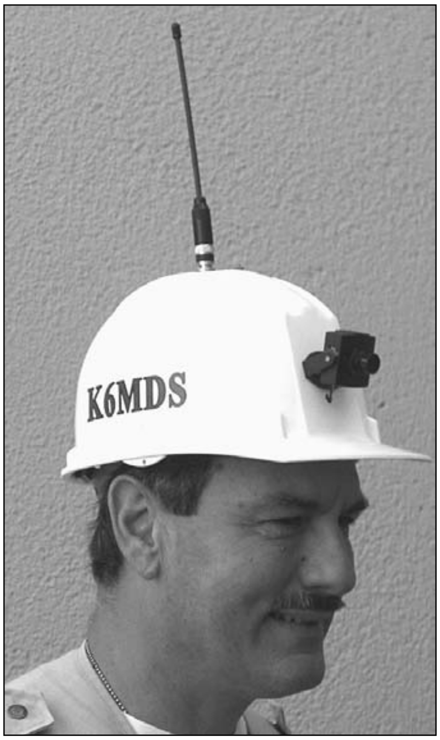


Fig 24 — Michael Saculla, K6MDS, built an ATV Hat Cam using a CMOS color camera along with a Videolynx 70 cm transmitter for public service applications.

Fig 25 — The tiny LB-1000 420-line CMOS color camera is typical of the many low-cost devices available. Intended primarily for security applications, they are popular with amateurs.

rial in each pixel *photocharges* a single CCD capacitor. The photogenerated charge on each capacitor is proportional to the amount of light striking the sensing element. The stored charges are then shifted out of the CCD array a line at a time as signals corresponding to each pixel. The resulting sequence of signal is similar to that of a vidicon scan. CCDs are the most common imaging device used in digital photographic cameras as well as video cameras, and they have very good low-light sensitivity.

Color CCDs use a screen, called a Bayer mask, over each square of four pixels. Each square has one for red, one for blue and two for green because the human eye is more sensitive to green. The luminance — gray scale — is sampled from every pixel. The possible lines of vertical resolution are determined by the number of pixels horizontally, but color resolution will be less because it comes from a square of four pixels.

When *lines of resolution* are given for a camera, this refers to the number of changes from vertical black lines to white that can be seen horizontally across the picture. While it is good to have a higher resolution camera — most are 380 lines or more — the picture will still be seen on a TV or monitor. In these display devices, response bandwidth limits luminance to about 240 lines and color to 100 lines in the NTSC system.

CMOS CAMERAS

CMOS active pixel sensors are a newer development and are replacing CCDs in imaging products. CMOS cameras have lower current requirements, lower price and less image lag, making them popular in cell phones. Amateurs use them for portable ATV applications such as the hat cam in **Fig 24**. A small CCD color camera may draw 120 mA while a comparable CMOS version draws 50 mA.

At first glance, board-level cameras are lighter for weight-sensitive applications like R/C and balloon vehicles, but those housed in a metal case are preferred to afford shielding from the effects of RF getting into the circuitry. The CMOS camera shown in **Fig 25** only weighs 3 oz in a 1.5-inch square metal case. It also includes a mic with line level audio output.

5 Glossary of ATV Terms

Aspect ratio — Image width divided by its height. Standard definition analog television uses an aspect ratio of 4:3 and broadcast HDTV uses 16:9.

ATSC — Advanced Television Systems Committee, the group that defined the set of standards and formats for the digital television formats implemented in the Broadcast Television Service. See **DTV**.

ATV — Amateur Television. Sending pictures by Amateur Radio. You'd expect this abbreviation to apply equally to fast-scan television (FSTV), slow-scan television (SSTV) and facsimile (fax), but it's generally applied only to FSTV.

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

Black level — The signal level amplitude that corresponds to the black end of the video dynamic range.

Blanking — A "blacker-than-black" signal level that assures that the scanning trace cannot be seen as it is reset to scan another line or frame. In conventional television this is often referred to as the *blanking pedestal*, consisting of two segments — the **front porch** that precedes the vertical sync pulse and the **back porch** that follows the sync pulse.

Cathode ray tube (CRT) — A specialized electron tube, employing a phosphor-coated screen, used for image display. The classic TV "picture tube" used in older television sets and computer monitors, is an example of such a tube.

Charge-coupled device (CCD) — An integrated circuit that uses a combination of analog and digital circuitry to sample and store analog signal voltage levels, passing the voltages through a capacitor string to the circuit output.

Chrominance — The color component of a video signal. NTSC and PAL transmit color images as a black-and-white compatible luminance signal along with a color subcarrier. The subcarrier phase represents the hue and the subcarrier's amplitude is the saturation.

Color burst — Seven cycles of a 3.58 MHz subcarrier signal located on the back porch (see **blanking**) of an NTSC color TV signal waveform. This short burst is locked on to by a PLL in the TV receiver as the reference for the chroma in the video.

Color subcarrier — The modulated 3.58 MHz component of an NTSC color television signal that is used to convey the color or luminance image data.

Composite video — The standard 1 V peak to peak analog video into 75 Ω load signal consisting of color, video, blanking and sync found in consumer products and typically identified with a yellow color coded RCA connector. The sync tip is referenced at 0 V, blanking at 0.285 V, black level at 0.339 V and white at 1.0 V.

Compression — Various digital techniques to reduce the bandwidth, transmission rate or file size of an image.

Deflection — the circuits or other components controlling the vertical and horizontal sweep signals that move the scanning beam of a cathode ray tube image display.

DTV — Digital television, most commonly applied to a series of 16 digital formats (including HDTV or High Definition Television) that comprise the default commercial broadcast digital TV standards in the United States.

DVB-S — Digital Video Broadcast - Satellite.

DVB-T — Digital Video Broadcast - Terrestrial.

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. NTSC has 525 lines per frame with about 483 usable after subtracting vertical sync and a few lines at the top containing various information.

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

FSTV — Fast-Scan TV. Same as common, full-color, motion commercial broadcast TV.

Interlaced scanning — A scanning pattern, designed to reduce perceived flicker in broadcast television systems, in which the complete image frame is actually made up from two sequentially-scanned fields and thus improving the vertical resolution. The timing of the sequential scanning is such that the lines of the second field are interspersed between the lines of the first field. For example, NTSC sends a field with just the even lines in 1⁄60 second, then a field with just the odd lines in 1⁄60 second.

Luminance — The brightness component of a video signal and can refer to the white-to-black amplitude or the chroma weighted sum of the gamma-compressed R'G'B' components computed as Y (the luminance signal) = 0.59 G (green) + 0.30 R (red) + 0.11 B (blue).

MPEG — Motion Picture Experts Group, a set of digital image compression formats/standards for moving images.

NTSC — National Television System Committee. Analog broadcast television standard used in North America and Japan.

PAL — Phase alteration line. Analog television standard used in Germany and many other parts of Europe.

Progressive scanning — A scanning sequence in which all image lines are scanned sequentially to display the complete image frame. Used in some **DTV** broadcasts.

Pixel — Picture element, the dots that make up images on a monitor. Image resolution is directly related to the number of picture elements. If the size of a picture element is large relative to total image size, the image will be made up of a relatively small number of picture elements and thus have relatively poor resolution. If the size of a picture element is small relative to total image size, the image will consist of a large number of picture elements and thus demonstrate better resolution.

Raster — The pattern of scanning lines developed on the face of a cathode ray tube during the display of one image frame.

Resolution — The ability to see a number of vertical lines horizontally across the screen. The NTSC analog horizontal scan rate of 15734 Hz limits the luminance resolution to 80 lines per MHz of video response bandwidth. Digital TV's highest resolution is limited by the number of screen pixels. It takes 2 adjacent pixels, one black and one white for one line.

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.

SECAM — Sequential color and memory. Analog television standard used in France and the Commonwealth of Independent States.

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).

Vidicon tube — A type of photosensitive vacuum tube used in TV cameras.

White level — The white end of the video dynamic range in any image transmission format. The difference between white and black levels defines the video dynamic range of the mode.

8-VSB — 8-level Vestigial Side Band, the standard for broadcast **DTV** in the US.

6 Slow-Scan Television (SSTV) Overview

The previous sections discussed fast-scan amateur television, used to send wide-bandwidth full motion video in the 420 MHz and higher bands. In contrast, slow-scan television (SSTV) is a method of sending still images in a narrow bandwidth and is widely used on the HF bands, although SSTV is sent via FM repeaters and amateur satellites too. **Fig 26** shows a sample image.

Fig 26 — Color SSTV image received from the International Space Station in Martin 1 mode 10/12/08 on 145.800 MHz FM.

Images are our most powerful communication tool. They can make us understand and remember better than any of our other senses. 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. As with any activity, the more involved you become, the more knowledgeable you become about all the intricacies.

SSTV is also a great way to get others involved in Amateur Radio or enhance other activities. Consider adding SSTV capability to your emergency communications, public service, Field Day or Jamboree on the Air station.

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

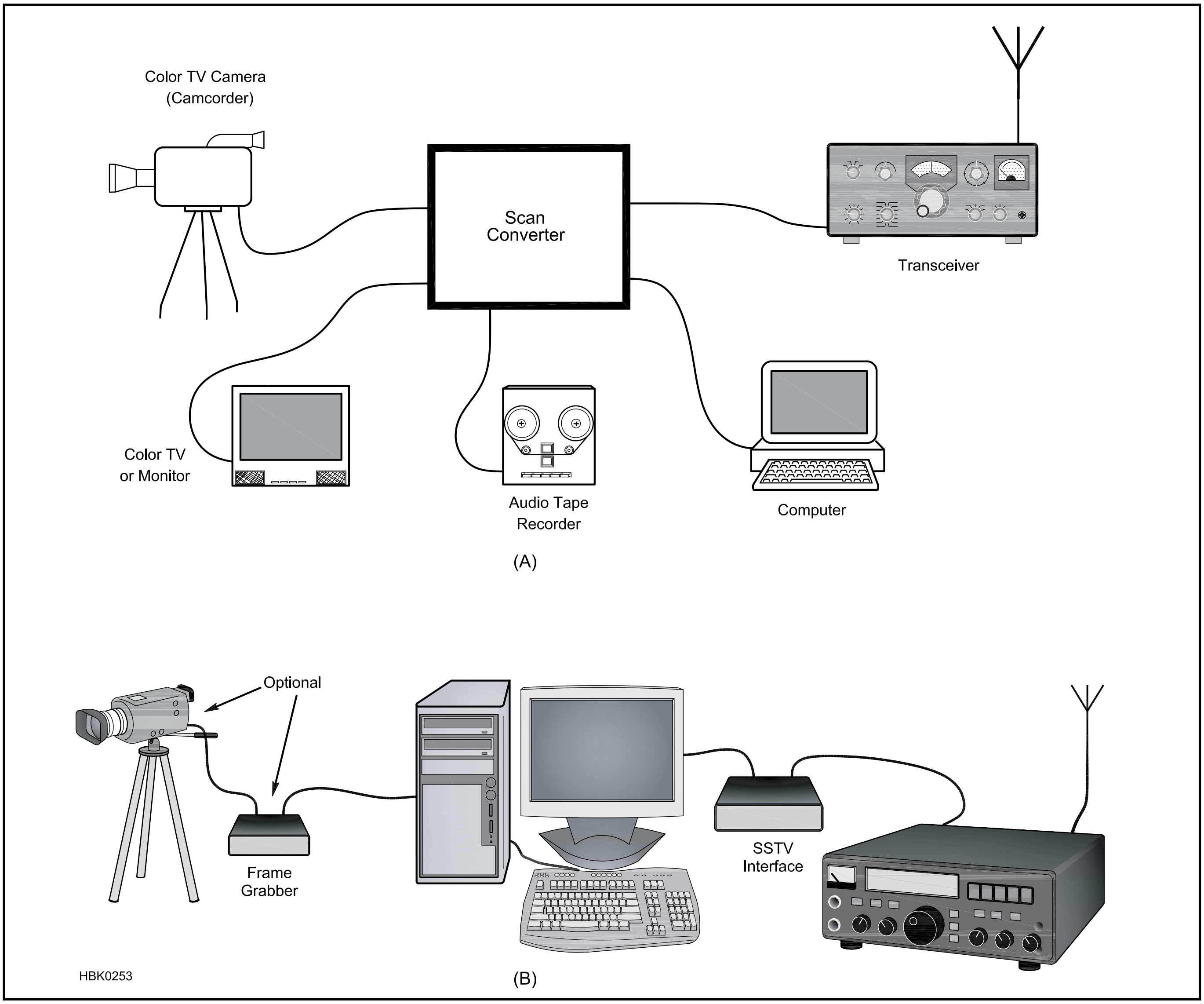


Fig 27 — Older SSTV stations required a dedicated hardware scan converter (A). Modern stations need only a sound card equipped PC and simple interface to send and receive SSTV (B).

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.

Copthorne Macdonald, WA2BCW, now VY2CM, developed the first SSTV system. In 1958, MacDonald used a surplus long-persistence phosphor radar monitor to display SSTV images. The images were created 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 (that's where the 8 seconds fits in). Three frames were sent back-to-back to maintain an image on the monitor. For many years, home-built systems were the only way to participate in SSTV. These were bulky, expensive and complex.

Robot Research produced SSTV equipment throughout the 1970s and 1980s. Their Robot 1200C scan converter, introduced in 1984, represented a giant leap forward for SSTV — all the SSTV functions were performed within a single box. (A *scan converter* is a device that converts signals from one TV standard to another. In this case, it converted SSTV signals to and from devices intended for fast scan television.) With updates and modifications, many 1200Cs are still in use today.

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 had an external box that processed the audio and performed 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 any more.

The personal computer with sound card has become the hardware of choice to send and receive images, replacing specialized devices. Today's powerful PCs and SSTV software are the heart of a modern SSTV station. The PC processes the incoming and outgoing SSTV audio using the sound card, while the software manages the acquisition, storage, selection and editing of the SSTV pictures. If you have a PC in your ham station, adding software and an interface (to connect the computer sound card to the transceiver) is all that it takes to get started in this fascinating mode. **Fig 27** compares a current station SSTV configuration to one from the 1990s.

7 SSTV Basics

Traditional SSTV is an analog mode, but in recent years several digital SSTV systems have been developed. All make use of standard Amateur Radio transceivers — no special radio gear or antennas required. SSTV transmissions require only the bandwidth of SSB voice, and they are allowed on any frequencies in the HF and higher bands where SSB voice is permitted. SSTV does not produce full motion video or streaming video.

7.1 Computers and Sound Cards

A computer with sound card is required to use most of the software popular for SSTV. Software for the *Windows* operating system is the most popular, but other choices are available. Hardware and software setup is similar to that described for sound card modes in the **Digital Communications** supplement on the *Handboook* CD for additional information.

The sound card characteristics discussed in the **Digital Communications** supplement apply for SSTV as well. 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. Equalizer and special effects should not be used. *Windows* sounds should be disabled to prevent them from going out along with the transmitted SSTV audio. The Recording control is used to select the input for receiving the SSTV audio. Adjust Line In or Microphone as needed for the proper level. Mic Boost should not be used.

7.2 Transceiver Interface

Interfacing the transceiver to the PC sound card can be as simple as connecting a couple of audio patch cables. Sound cards generally have stereo miniature 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. Ground loop problems may be avoided by using an audio isolation transformer.

The connection for receiving the SSTV audio from the transceiver may be made anywhere that received audio is available. The best choice is one that provides a fixed-level AF 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 the transmitted SSTV audio output. The cable for transmitted SSTV audio should go to the AFSK connection. If the transceiver does not have a jack for this, then the microphone jack must be used — requiring a more elaborate interface. TR keying can be provided 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-control command.

Commercially made and kit sound card interfaces are available. 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 its use along with the ease of operation when setting up for SSTV.

For more information on interfaces and adjustments, see the **Digital Communications** supplement on the *Handboook* CD. Another useful resource is the sound card interface Web page by Ernie Mills, WM2U, at **www.qsl.net/wm2u/interface.html.**

7.3 Transceiver Requirements

An SSB voice transceiver with a stable VFO is necessary for proper SSTV operation. The VFO should be calibrated and adjusted to be within 35 Hz of the dial frequency (more on this later). The transceiver's audio bandwidth should not be constrained so as to infringe on the audio spectrum used by SSTV. Optional filters should be turned off unless they can be set to 3 kHz or wider. SSTV software has its own DSP signal processing tools, so they are not needed in the transceiver. Most of the other transceiver settings should be turned off, including transmit or receive audio equalization, noise blanker or noise reduction, compression or speech processing, and passband tuning or IF shift.

Adjust your transmitter output for proper operation with the microphone first, according to instructions in your manual. Then adjust the sound card output for desired drive level. For SSB operation, receiving stations should see about the same S-meter reading on the SSTV signal as for voice. Properly adjusted levels and clean audio quality will improve the reception of the transmitted signal as well as reduce interference on adjacent frequencies. The SSTV signal is 100% duty cycle. If your transceiver is not designed for extended full-power operation, reduce the power output using the *Windows* Volume Control.

SSTV may be transmitted using AM, FM or SSB. Use the same mode as you would use for voice operation on a given frequency. On HF, use the same sideband normally used for voice on that band. SSTV activity can be found on HF, VHF, UHF, repeaters, satellites, VoIP on the Internet and almost anywhere a voice signal can get through.

7.4 SSTV Operating Practices

Analog SSTV images are, in a sense, broadcast. They arrive as-is and do not require the recipient to establish a two-way connection. Most SSTV operation takes place on or near specific frequencies. Common analog SSTV frequencies include 3.845, 3.857 and 7.171 MHz in LSB and 14.227, 14.230, 21.340 and 28.680 MHz in USB. Establish a contact by voice first before sending SSTV. If no signals can be heard, on voice ask if there is anyone sending. It may be that someone is sending but you cannot hear them. If there is no response, then try sending a "CQ picture." Note that on popular frequencies, weak signals can often be heard. In this case, wait for traffic to finish before sending SSTV even if you got no response to your voice inquiry.

Receiving SSTV pictures is automatic as long as your software supports the mode used for transmission (more on SSTV modes in later sections). Once a picture is received, it will be displayed and may be saved.

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, band conditions, signal strengths and the recipient's receive capability. Announce the SSTV mode prior to sending. Avoid sending a CW ID unless required by regulations. Describe the picture only after it is confirmed that it was properly received.

To send SSTV, 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. Click the transmit button, and your transceiver will go into 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 because it may not start scanning from the top.

SOURCE FOR IMAGES

The Internet is a popular source for images. With the unlimited number of images available, it is surprising how often the same internet pictures keep popping up on SSTV. Use a little imagination and come up with something original.

A digital camera is one of the best ways to create an original picture of your own. The subject matter could be almost anything that you might have available. Pictures of the shack, equipment and operator are always welcomed. A live camera or Web cam can provide an almost instant snapshot. Please keep your shirt on and comb your hair!

For those who like to discuss technical details, diagrams and schematics might be your ammunition. 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 hitting the PRINT SCREEN key on the keyboard. Use the Paste function in *Windows* to transfer the image to your SSTV or image editing software.

Any image editing program can be used to make your own CQ picture, test pattern, video QSL card or 73 picture. 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.

It is common to have call sign, location and perhaps a short description as text on the pictures. If two calls are placed on an image, it is understood that the sender's call is placed last. Signal reports may also be included. Once the images are saved, they provide a convenient confirmation of contact.

8 Analog SSTV

With slow scan, the fastest frame rate is 8 seconds so full motion video is not possible. Analog SSTV uses only a single frequency at a time. A 1200-Hz sync pulse is sent at the beginning of each line. Pure black is represented by a 1500 Hz tone, and 2300 Hz is used for pure white. Tones between 1500 and 2300 Hz produce the grayscale. The frequency varies with the brightness level for each pixel. Since it is only the change in frequency that makes up the analog SSTV signal, it is considered frequency modulated. Amplitude is not important other than getting over the noise. Analog SSTV uses less bandwidth than voice.

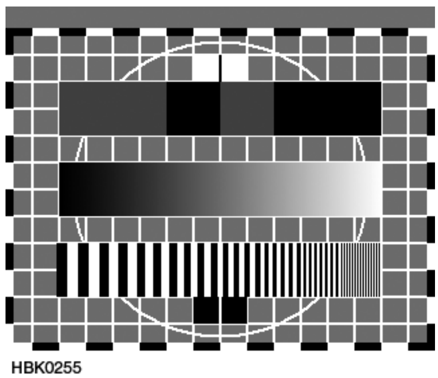


Fig 28 — This color test pattern is 320 × 256 resolution. The Robot modes from the 1980s only used 240 lines. CRTs were 4:3 aspect ratio, so the images were displayed in 320 × 240 resolution. When Scottie 1 and Martin 1 modes were added, they kept this resolution but added 16 header lines to the top 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.

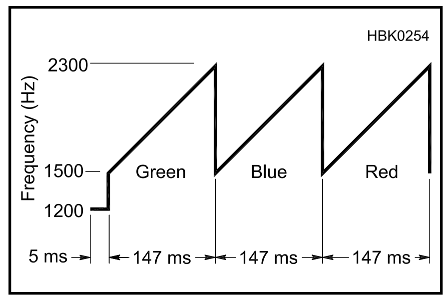


Fig 29 — This is a diagram of a single scan line of a Martin 1 transmission. The full frame includes 256 horizontal scan lines starting at the top. Before each line, a 1200 Hz tone for 5 ms is sent for synchronization. The pixels are scanned left to right and the colors are sent sequentially. First the 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.

8.1 Color SSTV Modes

Two popular modes for sending and receiving color SSTV pictures are called Martin and Scottie (named after their developers). Within each family are several different modes (Martin 1, Martin 2 and so forth). The various modes have different resolutions and scan rates.

Information about the size or resolution for each mode is generally available in the SSTV software. Better quality images will result when the source image is sized and cropped to the same dimensions used by the mode with which it is transmitted. Slower scan rates can provide better quality; those are the modes that take longer to send for the same resolution.

For example, Scottie 1 and Martin 1 are popular RGB (red, green, blue) color modes that take about two minutes to send a frame, with only one frame sent at a time. The image size sent is 320 × 256 — 320 pixels across with 256 lines. See **Figs 28** and **29**. True color is possible since each pixel is sent with 256 possible levels for each of the three color components (red, green and blue).

Each mode has a vertical interval signaling (VIS) code that identifies the mode being sent. The VIS codes use 1100 Hz for 1, 1300 Hz for 0, and 1200 Hz for start and stop. When these tones are received, it readies the system to receive in the proper SSTV mode.

For VIS 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 station sending is far off frequency, use the 1200 Hz sync signal in the spectrum or waterfall as a guide to adjust the VFO.

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 or transceiver settings 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.

Under good conditions, images may come

Table 2
SSTV Software

Windows	
Analog SSTV	
ChromaPIX	**barberdsp.com/cpix/chroma.htm**
MMSSTV	**mmhamsoft.amateur-radio.ca/mmsstv/index.htm**
Mscan	**mscan.com/?page_id=2**
ROY1	**roy1.com/download_ita.htm**
SSTV32	**webpages.charter.net/jamie_5**
W95SSTV	**barberdsp.com/w95sstv/w95sstv.htm**
Multimode	
JVComm32	**jvcomm.de/index_e.html**
MixW	**www.mixw.net**
MultiPSK	**f6cte.free.fr/index_anglais.htm**
Digital SSTV	
DIGTRX	**qslnet.de/member/py4zbz/hdsstv/HamDRM.htm**
EasyPal	**www.vk4aes.com**
WinDRM	**n1su.com/windrm**
MacOS	
MultiMode	**www.blackcatsystems.com/software/multimode.html**
MultiScan	**web.me.com/kd6cji/MacSSTV**
Linux	
MMSSTV	**mmhamsoft.amateur-radio.ca/mmsstv/index.htm**
QSSTV	**users.telenet.be/on4qz**
Amiga	
AVT	**datapipe-blackbeltsystems.com/amiga.html**

For links to additional software and notes on setup and operation, see **www.tima.com/~djones**

in "closed circuit." This means that the quality appears nearly as good as a photograph. SSTV has a reporting system similar to the RST reporting system used on CW. For analog SSTV it is RSV — readability, signal strength and *video*. Video uses a scale of 1 to 5, so a report of 595 would be the same as closed circuit.

8.2 Analog SSTV Software

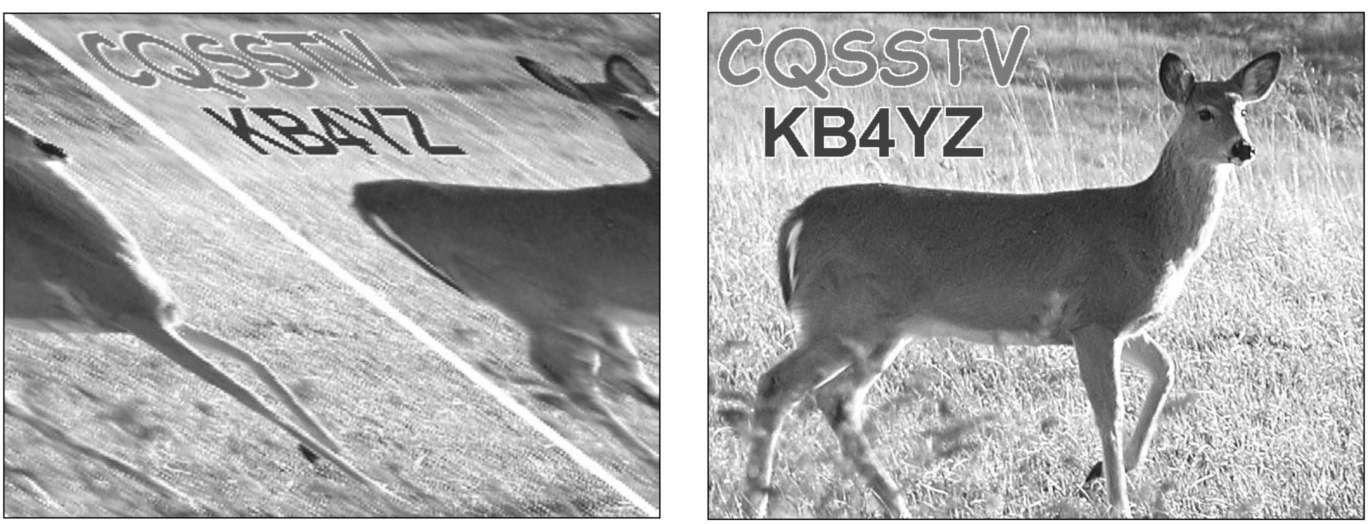
A variety of software programs are available for SSTV (see **Table 2**). Some multimode programs include SSTV and digital modes, while others are dedicated to SSTV. One very popular SSTV package is the *Windows* program *MMSSTV* by Mako Mori, JE3HHT. For more information or to download a copy, visit **mmhamsoft.amateur-radio.ca/mmsstv/index.htm**. *MMSSTV* will run on a 100 MHz PC, but some features may require a faster processor. Other SSTV software has similar features.

As explained in the **Digital Communications** supplement on the *Handboook* CD, sound card sample rate accuracy is important for some modes. Analog SSTV is one of them: pictures will appear *slanted* if the clock is off. See **Fig 30**. 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.

8.3 Resources

The International Visual Communications Association (IVCA) net meets each Saturday morning at 1500 UTC on 14.230 MHz USB. The net control will ask for check-ins and get each station to send a picture in Scottie 1 mode. Replays are sent in Scottie 2 mode. This will provide a way to see how well your pictures were received. Signal reports are welcome and brief questions may be asked. Anything more involved should be held until the net is over. Anyone may check-in to the net.

Information about the IVCA is available on Yahoo Groups: **groups.yahoo.com/group/ivca**. The *MMSSTV* Yahoo group is another valuable resource: **groups.yahoo.com/group/MM-SSTV**.



(A) (B)

Fig 30 — 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.

9 Digital SSTV

Several forms of digital SSTV have been developed, but the modulation method most widely used for digital SSTV as of 2009 is derived from the shortwave broadcast system Digital Radio Mondiale (DRM). (See the **Digital Communications** supplement on the *Handboook* CD for more information on the Amateur Radio voice applications of DRM.) *HamDRM* by Francesco Lanza, HB9TLK, is a variation of DRM that fits in a 2.5 kHz bandwidth and is used in various programs.

The DRM digital SSTV signal occupies the bandwidth between 350 and 2750 Hz (see **Fig 31**). As many as 57 subcarriers may be sent 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 400 ms duration, and several methods of error correction are used within the segments. (See the **Modulation** chapter for more information on ODFM and QAM.)

Digital SSTV using DRM is not a weak signal mode like the narrow bandwidth data modes such as PSK31. An S9 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 is received.

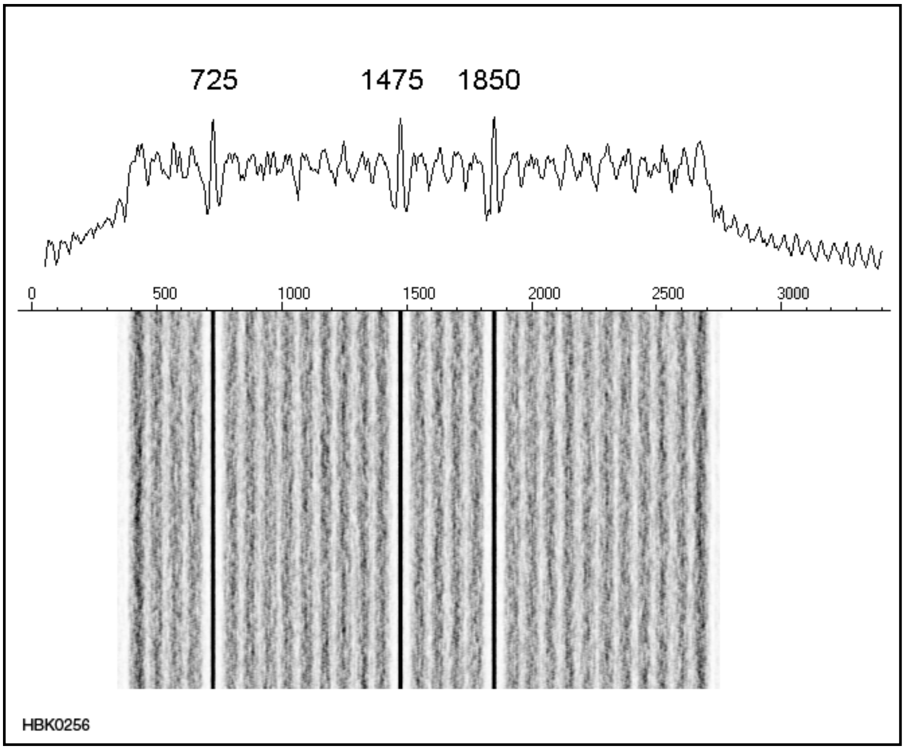


Fig 31 — DRM signal spectrum above and waterfall below. DRM transmissions may have slightly different characteristics due to the many possible submodes. All DRM transmissions used in Amateur Radio have three pilot carriers that have an amplitude twice that of the remaining subcarriers. These pilot carriers are found at 725, 1475 and 1850 Hz and aid in adjusting the frequency of the receiver to match the transmitted signal. The DRM TUNE signal also matches these three carriers. Software can compensate for mistune for as much as ±100 Hz, but only if the difference remains 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 also be nearly the same intensity across the full width. 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.

9.1 Digital SSTV Setup

A popular DRM digital SSTV program is *EasyPal* by Erik Sundstrup, VK4AES (**www.vk4aes.com**). Digital SSTV uses the same type of PC and sound card setup described in the analog SSTV section, 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. Software will also automatically adjust ±100 Hz for mistuned frequency.

With DRM SSTV the call sign is sent continuously. This may allow others to identify the transmitting station and perhaps turn an antenna in the right direction for better reception. Many submodes are available, with various transmission speeds and levels of robustness. The submode is 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. Avoid capacitors in the audio lines as they may interfere with the phase of the digital signal.

DRM audio levels are low, so there may be problems getting the signal to trigger a VOX circuit. 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.

9.2 Operating Digital SSTV

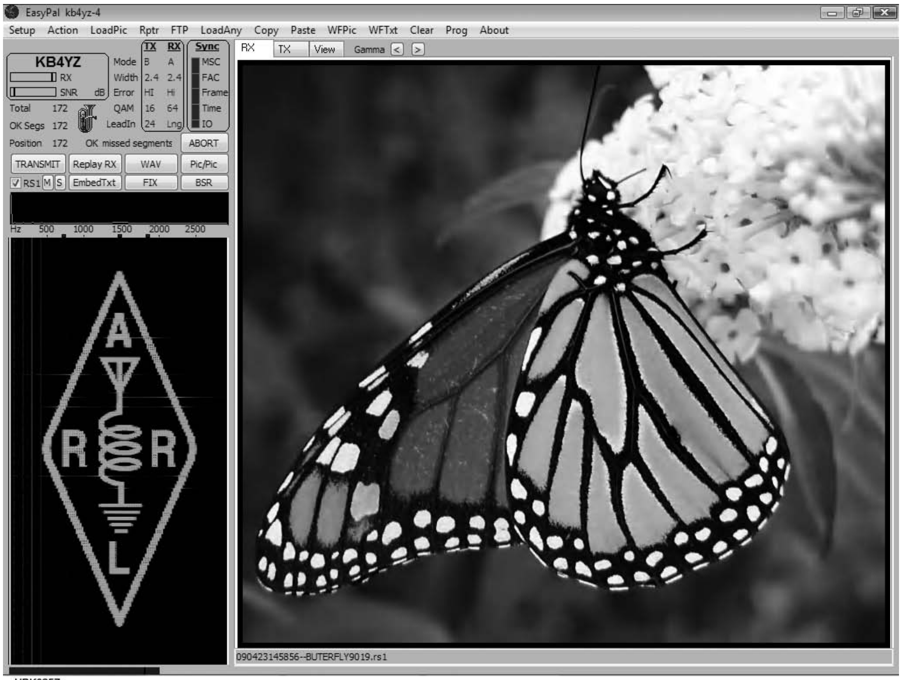
Before jumping into digital SSTV, try analog SSTV first. Copy some pictures to see if the sound card setup works. The level adjustments for analog SSTV are not as critical as those for DRM.

Common DRM SSTV frequencies include 3.847, 7.173, 7.183 MHz in LSB and 14.233 MHz in USB. Tune your VFO to the whole number in kHz (for example, 14,233.0). If a sending station is far off frequency, use the pilot carriers as seen in the software spectrum display as a guide. Adjusting the VFO while receiving an image is not advised as it will delay synchronization.

The signal-to-noise ratio (SNR) as displayed in the software is a measure of the received signal quality. The higher the SNR the better — decoding will be more reliable. Under very good band conditions this number may exceed 18. In that case, a higher speed mode may work. Because of the way the software measures the SNR, the peak value displayed for SNR may require 20-30 seconds of reception. Adjustments made on either end may change the SNR. Submodes with less data per segment take longer to send, but they are more robust and allow for 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



HBK0257

Fig 32 — *EasyPal* DRM digital SSTV software is used to exchange high quality, color images. Several levels of error correction and various transmission speeds are available.

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 only been partly received. In response, the other station can send a *FIX* 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 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 is in a position to 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. 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.

Fig 32 shows an *EasyPal* screen following successful reception of an image.

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 transmission time is the acceptable limit for the patience of most SSTV operators. A typical DRM 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 DRM signal will have a flat response 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 with all the subcarriers, the signal must be kept linear. Avoid overdriving the transmitter and keep the ALC at the low end of the 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 DRM.

In receiving DRM, 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 errors. Propagation and interference always play havoc. There is no substitute for a low noise location and good antenna when it comes to extracting the image from the ether. 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. You won't believe the quality of the pictures!

Help for all aspects of digital SSTV is available on Yahoo Groups DIGSSTV: **groups.yahoo.com/group/digsstv.**

9.3 Future of SSTV

Advancements in radio technology should make SSTV easier. Software defined radios (SDR) that make use of direct conversion of audio signals and use "virtual cables" internally may eliminate RF pickup and other forms of noise. Higher SNR should result. New transceivers that make use of optical cables may avoid problems with noise getting into or coming out of the sound card. All this could mean less distortion, lower noise levels and reduced hum and improved image quality. New digital SSTV systems will certainly be on the way. New features for DRM digital SSTV are being developed and new ways to use digital SSTV are discovered every day.

10 Glossary of 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.

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 standard 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.

SSTV — Slow Scan Television. Sending still images by means of audio tones on the MF/HF bands 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.

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 DRM transmission that lists all the missing segments for a file that has only been partly received.

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 consortium of broadcasters, manufacturers, research and governmental organizations which developed a system for digital sound broadcasting in bands between 100 kHz and 30 MHz. Amateurs use a modified version 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 DRM transmission that sends the data for all the segments for a received BSR.

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 4QAM, 16QAM or 64QAM.

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 64QAM, 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* provides four levels ranging from Very Light Encode (RS1) to Heavy Encode (RS4).

Segment — One MSC frame of an DRM file transmission. Contains file name or transport ID and data.

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

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For links to more information on SSTV, visit the "CQ SSTV" Web site: **www.tima.com/~djones/**.