Application Note
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ATV Handbook
- an Introduction to Amateur TV

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Chapter 1 - INTRODUCTION:

Television is an old rf communications technology dating back almost a hundred years to the 1920s. See the TV Time Line. table I, p. 3. The FCC early on allowed radio amateurs to experiment with TV for sending images. We amateurs break our ATV (i.e. Amateur TV) into what we call "Slow-Scan TV" and "Fast-Scan TV". Slow-Scan is used on the HF bands in narrow band voice channels and is only capable of sending still frame images at a very slow rate. It is essentially like sending a FAX. Fast-Scan is the same as the real, live images with motion which we watch over commercial broadcast TV. Because of the much wider bandwidth required for live images, all our Fast-Scan activity is restricted to the UHF and microwave bands, starting at the 70cm (420-450MHz) band.

Slow-Scan ATV will not be dealt with in this handbook. Likewise the transmission of images via IP technology will not be dealt with. This ATV handbook will deal with the various methods used for rf broadcasting of live, Fast-Scan, TV using both older analog and newer digital modulation schemes.

Fast Scan (live) TV is being used by amateurs for a variety of uses. One very popular use is with radio controlled (R/C) aircraft and other vehicles. The huge growing popularity of R/C drones is fueling this interest. Many drones today include an on-board TV camera to provide the pilot with a view from the cockpit. The buzz word for this is FPV, or First Person View. Hams for many years, as part of school STEM projects, have been doing high altitude balloon flights and including ATV and APRS transmitters as part of the balloon's payload. Another use, particularly relevant to our public service commitment is the use of ATV by ARES and RACES groups to provide live video coverage of large public events and disasters for our public safety, police and fire, officials. Beyond these, there is also the normal ham's desire to simply communicate with other hams. With ATV you can not only talk about ham radio, other interests, and family activities, but you can also actually show off your latest home brew project, or play a video tape of your most recent family vacation, etc. Most active ATV groups have weekly ATV nets for all members to share videos from their ham shacks. Most ATV groups also have a TV repeater to enhance their ATV coverage area.

This ATV handbook will cover the various aspects of how to get started in ATV dealing with video sources, types of TV modulation, transmitters, receivers, antennas, propagation, etc. It will conclude with a listing of ATV suppliers and references for further reading.

Table I --- TELEVISION TIME LINE

• 1925 – QST reports on TV experiments using mechanical scanning
• 1926 – John Blair in Scotland, demos 1st working TV using mechanical scanning
• 1927 – Philo Farnsworth, 1st patent for all electronic scanned TV system
• 1929 – 1st TV broadcast, BBC, London
• 1939 – NBS 1st live USA TV broadcast, New York City
• 1940 – 1st ham TV 2 way QSO, W2USA & W2DKJ in New York City, 56 & 112MHz
• 1941 - FCC issues NTSC standard, VUSB
• 1941-45 WWII, TV development suspended
• 1946-50 Major deployment of broadcast TV stations in all major metro areas
• 1948 – San Francisco bay area hams are transmitting NTSC TV on 70cm band
• 1950 – Ed Tilton, QST June issue reports on major ham TV activity in USA and Europe
• 1953 – Color added to TV, compatible with B&W
• 1957 – Cop McDonald, VY2CM, develops slow-scan TV for use on HF
• 1968 – Japan starts HDTV development
• 1986 – USA & Europe turn down Japan's proposal for their analog HDTV system
• 1987 - FCC creates ATSC to develop DTV
• 1991 - DVB development starts in Europe
• 1991-92 - FCC holds field trials for competing digital and analog HDTV systems
• 1993 - MPEG-2 video encoding standard adopted
• 1996 - FCC selects ATSC's 8-VSB system for broadcast DTV in USA with 10 year transition period from analog to digital
• 2009 - USA switches completely from analog TV to digital TV
• 2017 - FCC authorizes voluntary introduction of ATSC 3.0 (not compatible with 1.0)

Chapter 2 - BASICS OF TV VIDEO SIGNAL:

The basic concept of capturing a "live" video image consists of grabbing a sequence of still images at a fast enough rate that the human eye perceives them to be "live". In the motion picture industry, they found that a frame rate of 24 fps (frames per second) was sufficient. For TV, a frame rate of 30 fps (25 fps in Europe) is used. The historical reason for 30 fps rather than 24 was the presence of 60 Hz "hum" in the early day vacuum tube circuits. Using 1/2 * 60 Hz minimized the hum interference in video images. 50 Hz AC is used in Europe and most of the rest of the world, hence the 25 fps for their TV systems.

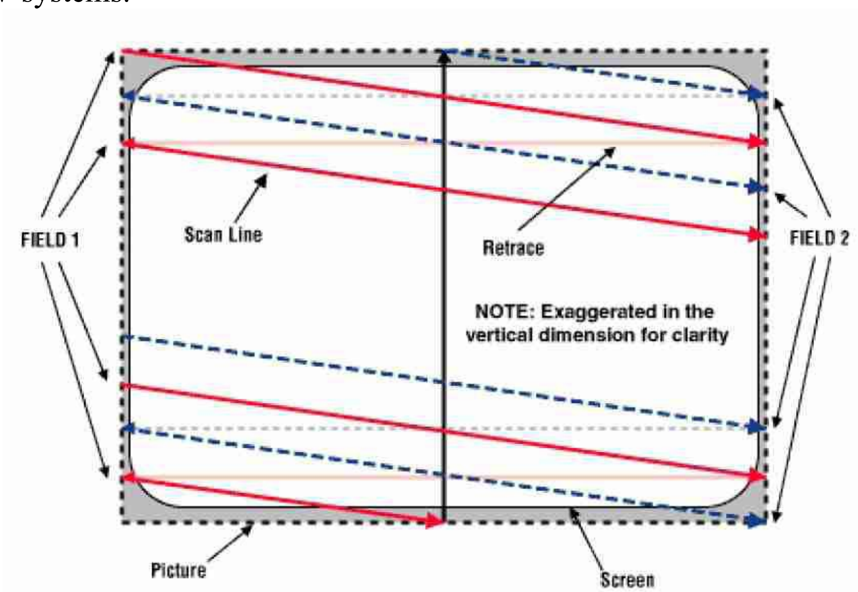


Fig. 1 Scanning on a CRT to display a TV image.

Until fairly recently, all of our TV receivers used a cathode ray tube (CRT) as the display device. A CRT presents a single spot (or pixel) on it's screen at any one time. The persistence in the phosphor made that spot glow for some time after it was illuminated by the electron beam. Thus, to present a complete image the electron beam needed to be swept (or scanned) sequentially across the CRT phosphor screen, from left to right and from top to bottom. To maintain synchronization between the initial image scanning camera and the display CRT a set of horizontal and vertical synchronizing pulses were required to maintain the proper timing.

During the early development of TV in the 1930s, many experiments were run, using the available technology of the time, and a set of TV standards were developed for scan rate, lines, etc. This was formulated by 1941, by the TV R&D people and the FCC into what is called the NTSC (National Television System Committee) standard. It resulted in the standard composite video signal with 525 horizontal scan lines at a 30 Hz frame rate. A CRT display would first sweep from left to right, then rapidly reset back to the left side of the screen and index down a line. See Fig. 1. When the scan finally reached the bottom of the screen, it would then be reset vertically to the top of the screen and a new frame would commence. These horizontal scan lines were interlaced with only 480 of them actually being visible. Hence the term 480 i. The remainder were masked during the vertical retrace time interval. The composite video signal is a 1 Vptp signal into 75 Ohms. See Fig. 2. The various levels were measured in IRE (Institute of Radio Engineers) units. 140 IRE = 1 Volt. The active video information occupied 100 IRE units and it could assume any value depending upon the gray level of the pixels. The horizontal and vertical sync pulses occupied 40 IRE units. The highest level was white. The lowest was the tip of the sync pulses. The vertical sync occurs at 29.97 Hz. The horizontal sync at 15.748 Hz. There are 525 lines per frame with 262.5 lines per field. Two interlaced fields make up a single frame. Thus for 480 i video we have 640 x 480 pixels.

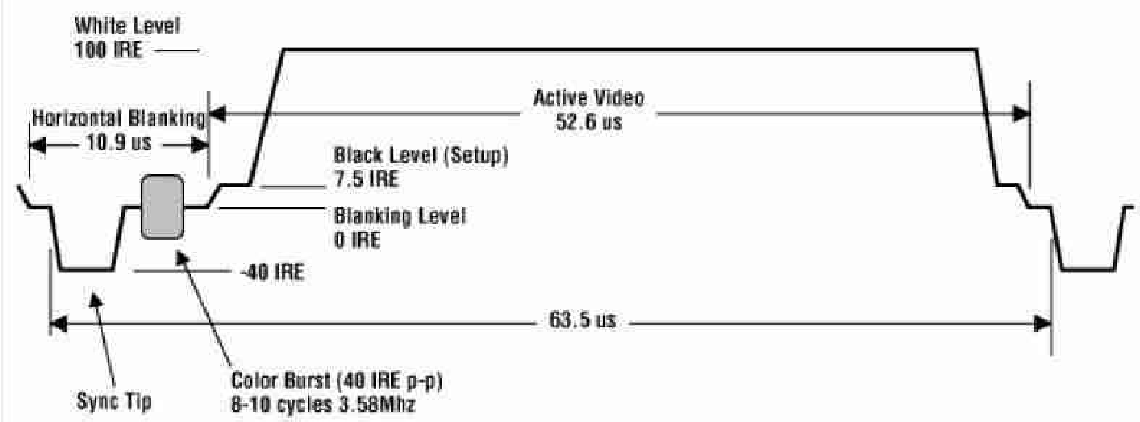
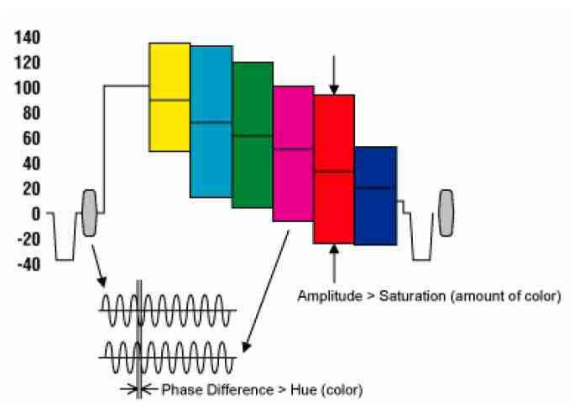


Fig. 2 Composite Video Signal, 1 Volt p-t-p into 75 Ohms One horizontal line shown.

In 1953, NTSC added color to the basic TV signal. The color system adopted was designed to be backwardly compatible with the original black & white TV. This was done by adding a color sub-carrier (CSC) of 3.58 MHz with independent sidebands carrying the color information. The color burst shown in Fig. 2 was used to synchronize the 3.58 MHz color local oscillator in the receiver. Fig 3 shows a composite video signal carrying color information for a color bar test pattern.



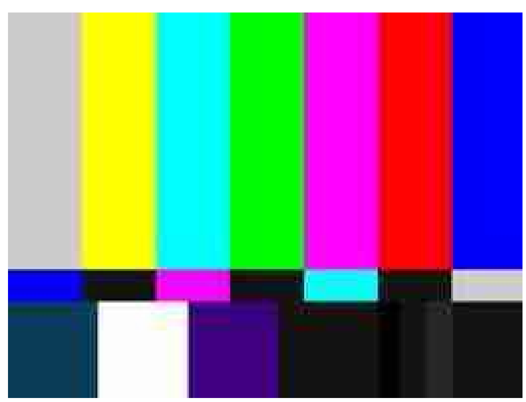


Fig. 3 Composite video signal with color bars & the resultant image on a video monitor.

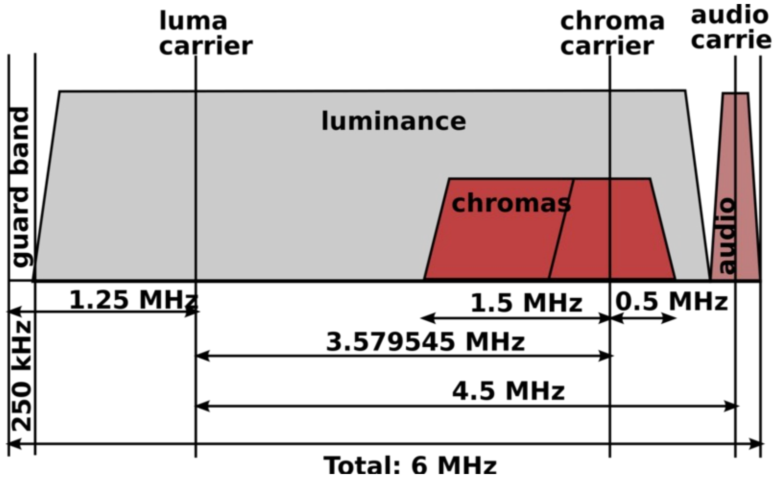


Fig. 4 The rf spectrum of an analog NTSC - TV signal.

The NTSC composite video signal's spectrum extended from the low 60 Hz sync rate of the vertical pulses up to an upper luminance (i.e. B&W) bandwidth of 4.2 MHz. The color (or chroma) information requires less bandwidth. It is carried via a 3.58 MHz color sub-carrier as independent upper and lower sidebands. When broadcast by the NTSC system, the composite, 4.2 MHz bandwidth video signal is first AM modulated onto an rf carrier. This would result in a double sideband rf signal occupying at least 8.4 MHz of bandwidth. To conserve bandwidth, the original NTSC standards called for filtering off all but 750 kHz of the lower sideband. The result is called a Vestigial Sideband (VSB) signal - or VUSB for Vestigial Upper Side-Band. The rf video carrier was placed 1.25 MHz up from the lower channel edge. Audio was then added using a separate FM transmitter, placed 4.5 MHz above the video carrier frequency. Fig. 4 shows the resultant spectrum. It occupies a 6 MHz wide TV channel with a 250 kHz guard band.

Chapter 3 - TV VIDEO SOURCES

The very first acquisition required if one is interested in getting on the air with ATV is a source of video. This should be a TV camera. You can spend as little as $5 or many thousands of dollars on a camera. There are a huge number of choices. Older, analog, TV cameras can be picked up at ham radio swapfests for next to nothing in cost. My personal recommendation is to go with a video camcorder. See Fig. 5. Very good, high definition (1080P), digital camcorders are now available new in the $200-$300 price range. They include: zoom lens, built in stereo microphones, built-in monitor screen, SD card memory, and battery / ac operation. They all provide their audio/video (A/V) output on an HDMI cable. They also have a USB port for transferring video to a computer. Some, but not all of the current production camcorders include an analog, composite (480i) video plus stereo line level audio output. Inexpensive ($10-$20), HDMI to Composite Video plus stereo audio adapters are available on the internet, if you also need composite analog video plus audio. With the built-in memory in a camcorder, you can record events and then play them back later over your ATV transmitter.

Fig. 5 Typical TV Camcorder used for ATV

Most modern SLR type digital cameras also include video recording ability. However, "Buyer Beware". You need to shop very carefully if you also want the SLR camera, or camcorder to function as your ATV camera. Features to look for that are relevant for ATV use. 1. Will the camera put out both video and audio on the HDMI cable in the stand-by mode? (some only put out video) 2. Will it put out both video and audio while recording? (some cameras only put out A/V on playback). 3. Is the resolution coming out of the A/V port the same as the camera records in ? (some record in hi-def, but only output std. def.) 4. Can you lock out the time-out timer? 5. Does the camera have auto-focus in the movie mode? (you want to be able to zoom the lens without manual focusing as a TV camera). Ask lots of questions of the sales clerk and ask for actual demos before purchasing.

Other sources of video include security cameras, VCRs, DVD players and your home PC computer. Most computers provide an output for an external monitor, plus a line level audio output. On older computers, the monitor output was in the VGA format. Newer model computers provide the monitor output using the HDMI format. HDMI is the common digital A/V cable found on all modern consumer video products. Again, if you need a different video format, inexpensive converters can be found readily on the internet. Your PC can also be your one and only video source. Today, they all come equipped with a built-in TV camera and microphone. Thus you can mix your own live image and voice with other material on your computer to present a multi-media production for your fellow ATV hams to watch.

Chapter 4 - AMATEUR TV BANDS

As shown previously, the original, analog, NTSC, TV transmissions required a 6 MHz wide channel. Modern day, commercial broadcast TV uses digital transmission, but still uses the same 6 MHz channels for each transmitter. All of our HF bands put together would not give us 6 MHz. We have to move up to the UHF region before we find enough bandwidth available to support TV. This means the first amateur band available for TV is our 70 cm band (420-450 MHz). It is 30 MHz wide and could support up to five, 6 MHz , TV channels. See Fig. 6. Our 70cm band is actually just below the commercial broadcast TV, UHF band which starts at 470 MHz. Note in Fig. 6 the designation of channel numbers 57 through 61. USA cable TV uses all of the spectrum from 54 MHz (Ch. 2) up to about 1 GHz, divided into adjacent 6 MHz channels. It turns out that CATV channels 57 through 61 actually land directly in the amateur 70cm band. This is fortunate, in that a 70 cm, analog, ATV transmitter's signal can be received directly on a home TV receiver. The ARRL band plan for the 70cm band calls for Ch 58 to be used for simplex TV while Ch 60 and Ch 57 are to be used as the input and output channels for a TV repeater. The use of the other channels for TV is not recommended due to likely RFI to FM voice repeaters on Ch 61 and weak signal SSB/CW and satellites on Ch 59. It should be noted that not all regions of the USA adhere to the ARRL band plan for ATV. Some regions use non standard frequencies. The most common being 426.25 MHz and 434 MHz for analog ATV.

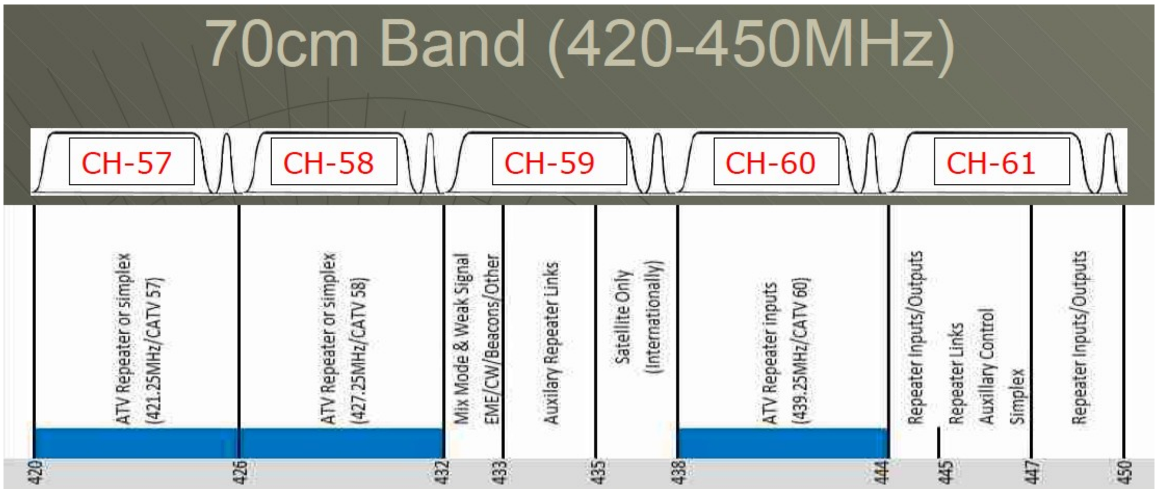


Fig. 6 ATV in the 70cm band

The 70 cm band is by far and away the most popular and most useful of all the amateur bands for ATV. It has the combination of good propagation characteristics, most available equipment, reasonable size antennas, etc. All of the higher frequency amateur bands can also be used for ATV. As one goes higher in frequency, these microwave bands become more useful for point-to-point TV links, rather than wide-area TV broadcasting. The next most popular band after 70 cms is the 23 cm band (1240 - 1300 MHz). With 60 MHz available, it could support up to ten, 6 MHz TV channels. In most areas, it is a fairly quiet band with much fewer users. The main issue for some large metro areas is the presence of government radars within the 23 cm band. They are primary there and amateur usage is secondary and we are not allowed to cause RFI to these radars.

The next bands in terms of usage for ATV are on either side of 23 cm. They are the 33 cm (902-928 MHz) and the 13 cm (2.39 - 2.45 GHz) bands. These bands are considerably less useful due to the shared usage with unlicensed, part 15 devices. The 2.4 GHz band is especially bad because of it's wide spread use for Wi-Fi. There is also some ATV activity in the higher microwave bands of 9 cm (3.3 - 3.5 GHz), 5 cm (5.65 - 5.925 GHz) and 3 cm (10 - 10.5 GHz). ARRL band plans exist for all of these various bands and specific channels have been set aside for ATV use.

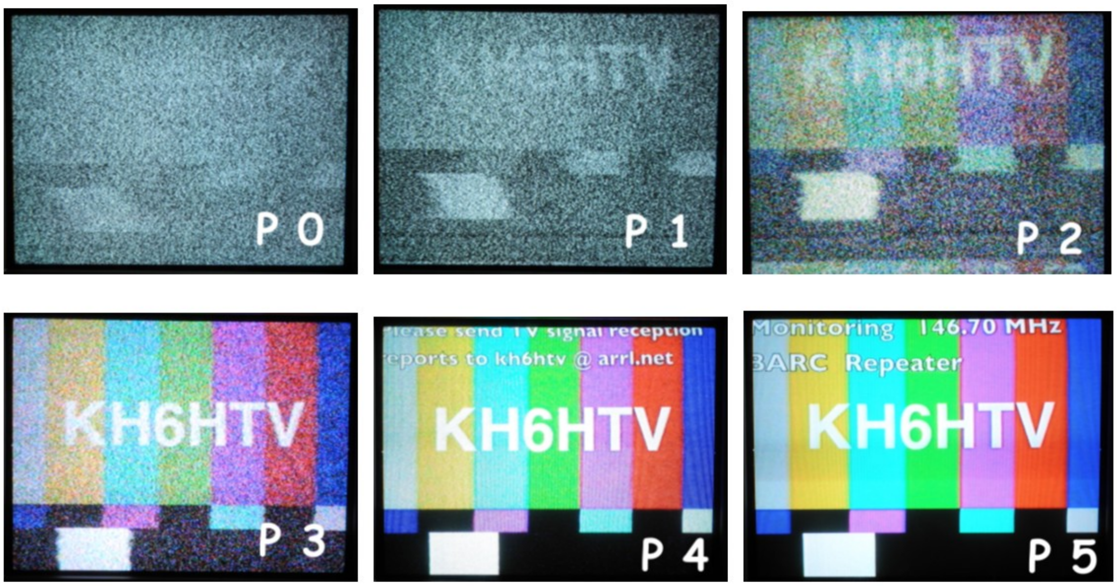


Fig. 7 ATV system of reporting Picture Quality

Chapter 5 P5 - TV SIGNAL QUALITY REPORTING

In HF radio we report signal reception using the RST method. R = Readability, S = Signal Strength and T = Tone (only used for CW). Thus a 5-9 report means perfectly readable with an S-9 on the S meter. For ATV we use a similar method for reporting the quality of the received image. We called it the P rating, i.e. Picture rating. Fig. 7 shows examples of various weak analog ATV signals and their respective P rating.

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

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

P2 Weak signal. Lot of snow present in image. Black and White only. No audio. Can detect presence of people in the image and movement. Not a useable picture for routine, pleasurable viewing. Note: some excellent receivers might show color with a P2 signal. Then instead of white "snow", you will experience a shower of colorful confetti !

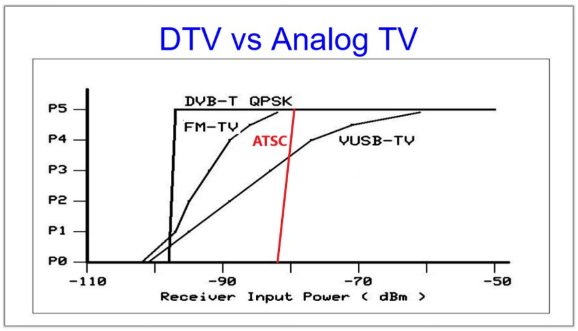
P3 Moderate signal. Still has snow present in image. Color lock. Audio is present, but noisy. Acceptable picture for people living in very rural areas watching broadcast TV.

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

P4.5 Strong signal. Only a very few, minor picture defects. A border line P5.

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

For VUSB (or AM) TV transmissions, to obtain a P5 picture requires an RF signal to noise ratio of S/N > 40 dB. For each P unit from P0 to P4, there is an increase in signal strength of 6 dB, i.e. the same definition as used for S units. For FM-TV, the FM quieting effect kicks in earlier and results in a considerably lower required S/N for good to excellent pictures.



P Units	VUSB-TV	FM-TV
P 0	0 dB	0 dB
P 1	6 dB	5 dB
P 2	12 dB	7 dB
P 3	18 dB	10 dB
P 4	24 dB	13 dB
P 4.5	30 dB	16 dB
P 5	40 dB	20 dB

Fig. 8 P Units vs. RF S/N for VUSB, FM TV & DTV Signals

It should be noted that most modern, flat-screen, TV receivers include a Video Squelch circuit and never display a totally noisy screen, but instead switch to a blue screen. The video squelch can not be disabled. Thus you may never see a P0, P1, or P2 image on these receivers. Older CRT TV receivers and monitors didn't have a video squelch.

For digital, DTV, P units are meaningless. With the "Cliff Effect" in DTV, we either have a perfect picture, i.e. P5, or no picture at all. At the edge of the digital cliff, we might see some "Pixelization" (i.e. breaking up of some pixels) before we fall off the cliff. This could be considered a P4 picture. The width of the digital cliff is about only 1 dB. Thus if you see pixelization occurring, you are right at the threshold and if you drop one more dB, your picture is lost completely.

Chapter 6 - TV MODULATION MODES

Amateur radio operators are presently using a multitude of various modulation modes for ATV, both analog and digital, Fig. 9. This is much like what has been occurring on the HF bands with the various methods used for SSTV and the various text digital modes. However, to obtain any base of interest in ATV in a particular geographic area, the selection of one single modulation method is to be encouraged. So if you are interested in getting started in ATV, it is best to inquire as to what modulation mode(s) are currently in use in your local area. There is nothing worse than setting up your ATV station and then having no viewers to exchange pictures with.

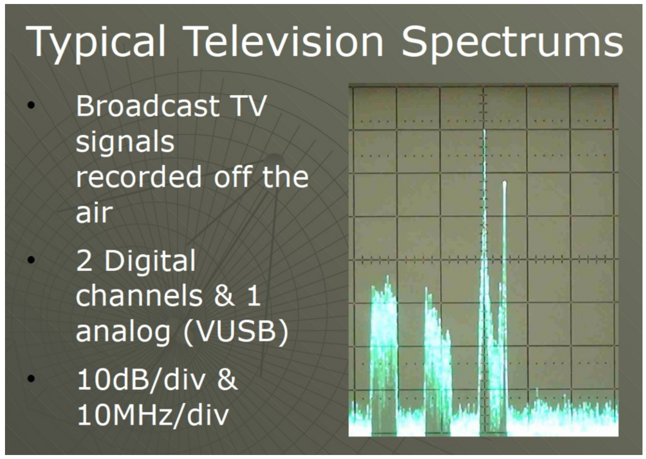


Fig. 9 Broadcast TV spectrums -- the future digital TV and the past analog TV.

In the past ATV hams used the old analog, NTSC, method, on the 70cm band with AM-TV and to a lesser extent on the 23cm band along with FM-TV. However, like is happening in other parts of amateur radio, there is a movement to transition over to digital modulations. Over ½ of the ATV repeaters in the USA have made the transition. For digital TV we use the acronym DTV. For DTV there are several modes to chose from. This section will discuss the pros and cons of analog modes of AM-TV, VUSB-TV and FM-TV, plus the digital modes of ATSC, CATV-DTV, DVB-S and DVB-T.

Table II -- Typical TV Receiver Sensitivities

Modulation	**Minimum Received Signal**	**Notes**	**Additional Notes**
VUSB-TV	-88 dBm	P2	
VUSB-TV	-60 dBm	P5	
FM-TV	-95 dBm	P2	
FM-TV	-84 dBm	P5	
ATSC	-93 dBm		
CATV-DTV	-80 dBm	64QAM	
CATV-DTV	-72 dBm	256QAM	
DVB-S	-95 dBm	6 MHz BW,	
DVB-T	-95 dBm	QPSK	6 MHz, BW, 1080P, 7/8 FEC
DVB-T	-90 dBm	16QAM	6 MHz, BW, 1080P, 7/8 FEC
DVB-T	-82 dBm	64QAM	6 MHz, BW, 1080P, 7/8 FEC
DVB-T	-100 dBm	QPSK	6 MHZ BW, 720P, 1/2 FEC
DVB-T	-104 dBm	QPSK	2 MHz BW, 480i, 1/2 FEC

Unlike commercial broadcast TV, amateurs do not have the luxury of running many tens of kilowatts of transmitter power from very tall antennas. Most ATV transmitters are very low power, typically 10 watts or less. A few ATV hams are running 100 watt transmitters. Thus selecting a modulation mode which can be received with the lowest power level is important. Table II above lists typical measured receiver sensitivities.

Adding a good, low noise preamplifier to the TV receiver typically enhances these values by 3 to 5 dB.

FIELD TESTS COMPARING ANALOG vs. DIGITAL TV: Amateurs have run field tests comparing analog vs. digital TV. The tests were run under identical conditions using the same rf power levels, antennas, locations, etc. Tests comparing either analog VUSB-TV or FM-TV vs. digital DVB-T (QPSK) gave these major conclusions:

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

DTV LATENCY: Aside from the fact of All or Nothing with DTV, i.e. perfect picture or no picture, the other major effect immediately noted is Latency, i.e. Delay. Due the very large amount of computer number crunching required for DTV, both in the transmitter and the receiver, all DTV transmissions are not really "live". There is always a measurable time delay from the original image "snap-shot" until it finally appears on the TV screen. Delays range from perhaps 1/2 second to several seconds. For relayed DTV signals, such as through a TV repeater, the delays build up sequentially. For this reason, the use of DTV is discouraged for safety reasons for applications such as piloting a remote R/C aircraft or drone.

ANALOG TV MODULATIONS: For analog TV, there are basically three modes in use. They are AM-TV, VUSB-TV and FM-TV. As discussed earlier in the Introduction, the NTSC standards were developed in the 1930s and early 40s. At that point in time, the method used for voice modulation of radio transmitters was AM or amplitude modulation. Thus, it was natural that AM also be used for their video TV experiments. The early engineers did however recognize the redundancy in having two identical sidebands in AM and found they could conserve bandwidth by filtering off a portion of the lower sideband, hence VUSB-TV. This became etched in stone with the FCC adoption of the NTSC standard in 1941. It remained in place for the next 68 years until 2009 when the USA switched over to DTV. Commercial broadcast TV stations typically used two transmitters. The Visual transmitter was AM modulated and used a sharp cut-off, band-pass filter to give VUSB-TV. A second, Aural transmitter was used for audio and it was an FM transmitter with it's frequency set 4.5 MHz above the visual transmitter. For ATV, AM-TV and VUSB-TV on 70cms can be received directly on any home TV receiver by tuning to cable channels 57 through 61. Table 32.2 showed that AM or VUSB-TV was the worst mode in terms of the required signal level at the receiver for a perfect picture. -60dBm was required. Thus the commercial broadcast TV stations had to run extremely high powered transmitters from very tall towers to get good pictures to their viewers.

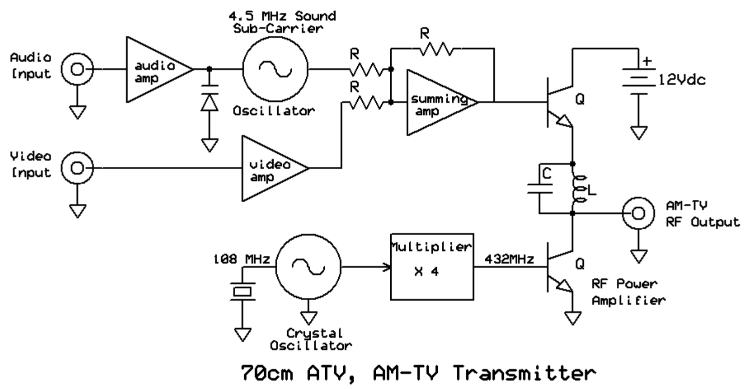


Fig. 10 Block diagram of typical amateur TV AM transmitter

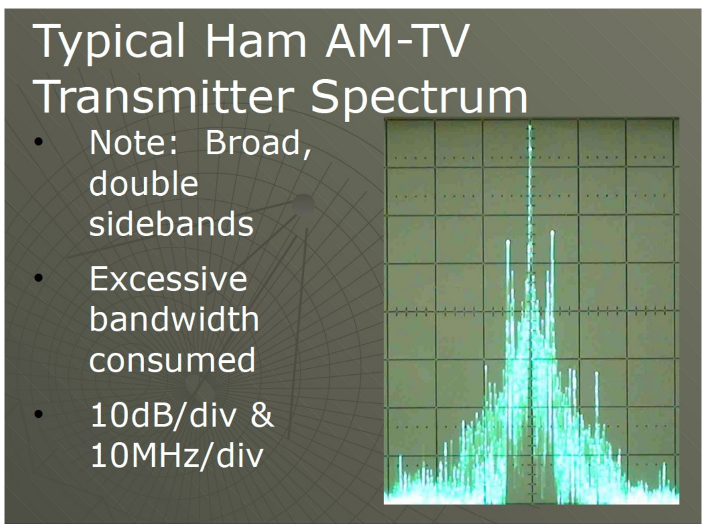


Fig. 11 Typical amateur AM-TV transmitter's spectrum

AM-TV: Most ATV hams in the past have used a much simpler approach for their TV transmitters. See Fig. 10 above. They first created a 4.5 MHz sound sub-carrier (SSC) with a varactor tuned oscillator FM modulated by their audio signal. They then mixed this 4.5 MHz SSC with their composite video signal in a summing operational amplifier circuit. This combined A/V signal was then used to AM modulate the finals in their transmitter. In the early days of ATV, grid modulation of the vacuum tube final amplifier was used. With transistor transmitters, the AM modulation was applied to the collector of the final rf power transistor. Early ATV transmitters were all crystal controlled. AM-TV transmitters are very wasteful of spectrum. See Fig. 11. The spectrum from a single amateur, AM-TV transmitter would cover the entire 30 MHz of the 70cm band. I recommend that the use of such AM-TV transmitters be discontinued, especially on the 70cm band. We really should be trying to adhere to broadcast TV standards where a maximum of 6 MHz of spectrum is occupied by their TV signals, especially on our valuable 70cm band.

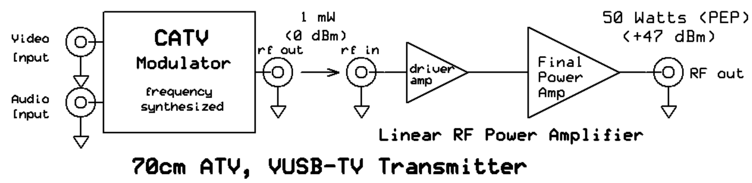


Fig. 12 Block diagram of an amateur TV VUSB transmitter

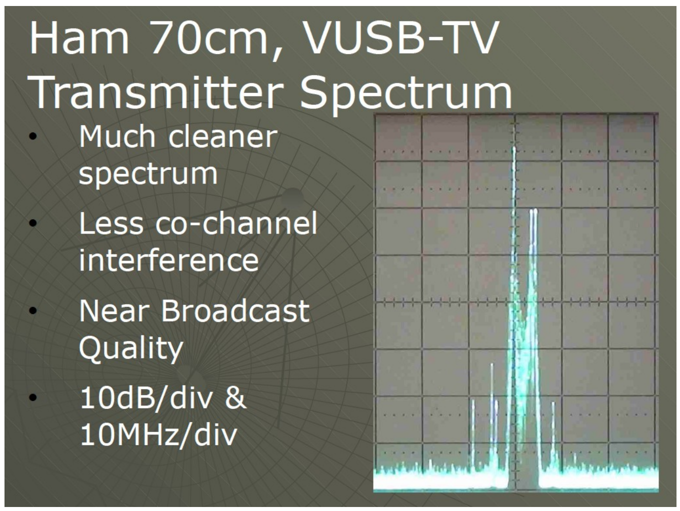


Fig. 13 Spectrum from an amateur VUSB-TV transmitter using a CATV modulator

VUSB-TV: It is possible for amateurs to have good quality, analog TV transmitters which adhere to the FCC, 6 MHz bandwidth limits, using VUSB. Simply adding to the output of an AM-TV transmitter, a 6 MHz wide, band-pass filter with steep skirts will accomplish this. Unfortunately, there are not many suppliers of such filters and they are expensive, thus most ATV hams have ignored this solution. Another recent approach is to use the analog TV modulators previously used in the cable TV industry to create a spectrally clean VUSB-TV signal at the low 1 mW (0dBm) level and then amplify it with an rf linear power amplifier. See Fig. 12 above. Fig. 13 is the spectrum from such a TV transmitter. It's spectrum is much cleaner compared to the AM-TV transmitter in Fig. 11. Unfortunately, now in 2026 with the transition to commercial broadcast digital TV, these CATV modulators are now considered obsolete. With careful google searches, they can still be found on the used, surplus market.

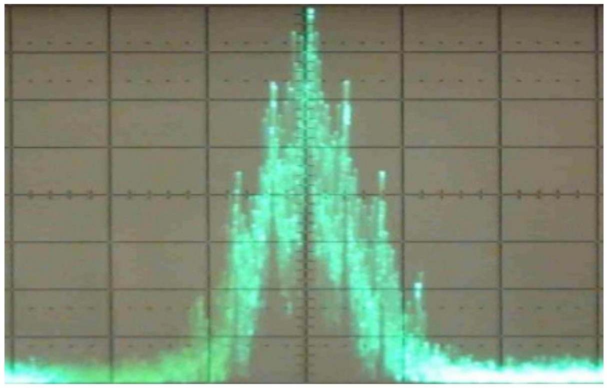


Fig. 14 Typical amateur FM-TV spectrum 10dB/div & 10MHz/div

FM-TV: Hams are well aware of the advantages of FM over AM modulation. We use FM almost exclusively on the 2 m and 70 cm bands for our voice radios. The same holds true for analog TV. FM-TV performs far better than AM-TV (or VUSB-TV). A full quieting, perfect picture can be received at much lower rf power levels with FM. To receive a perfect VUSB-TV signal requires a S/N of 40dB and a signal level about -60dBm. For a perfect FM-TV signal with the FM quieting effect, a S/N of 20dB results in a perfect picture at a signal level of about -84 dBm. In the broadcast TV industry, in the analog days, FM-TV was used exclusively for their electronic news gathering and for their point-to-point microwave links from studio to transmitter, etc. A typical amateur FM-TV transmitter uses 4 MHz deviation and a SSC in the range of 4.5 to 6.5 MHz. Fig. 124 shows the typical spectrum of such an FM-TV transmitter. It occupies about 15-20 MHz of spectrum. As such, the FM-TV spectrum is far too wide for the 70cm band and we do not use FM-TV on this band. There is room on the 33cm band for only one FM-TV channel and it is typically at 915 MHz. FM-TV is the prefered analog mode for ATV on the much wider 23cm band and the higher microwave bands. The most commonly used frequency on the 23 cm band is 1255 MHz.

DIGITAL TV MODULATIONS: For ATV, there are essentially four modes of digital modulation primarily used. They are CATV-DTV, ATSC (8-VSB), DVB-S and DVB-T. The first modes usually considered by amateurs for DTV use are ATSC and CATV-DTV because they can be received directly on a USA home TV receiver. The most popular, with the best performance however are DVB-S and DVB-T, using the European broadcast TV standards. Figs. 9 & 15 shows the typical spectrum of a digital TV signal. The spectrum of all the various DTV modes are similar. The DTV spectrum looks like white noise riding upon a rectangular pedestal. The white noise is uniformly spread over the entire TV channel. The "grass" seen on the baseline of the above spectrum plots is the noise floor of the spectrum analyzer. Tuning in a DTV signal on a SSB receiver sounds just like white noise, except that the S meter reveals the presence of additional rf power above the noise floor of the receiver.

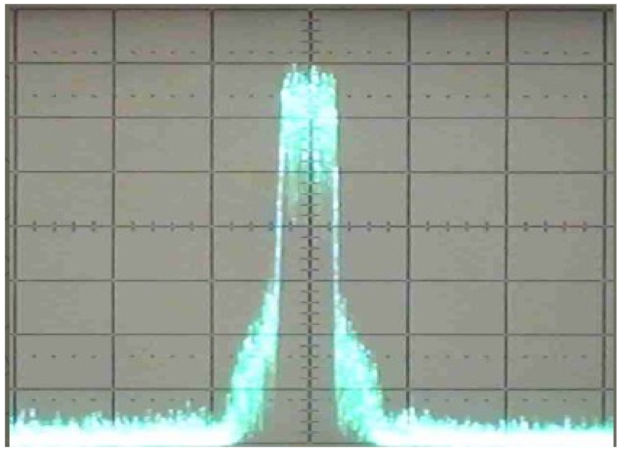


Fig. 15 Typical spectrum from an amateur DTV transmitter. 10dB/div & 10MHz/div

CATV-DTV (QAM): There are several variations, world-wide, on DTV for cable TV. In Europe and most of the rest of the world, it is DVB-C. In the USA, it is ITU-T_J.83-Annex B. It is also oftentimes simply called **QAM.** The cable environment is extremely friendly for rf transmission. It is a closed circuit, RFI free environment in which no multi-path exists. The cable companies take great pains to minimize reflections in their cable (i.e. low VSWR). The signal levels can also be kept high and well above the noise level. Various modulations from QPSK up to 256-QAM are used with 64-QAM being the most typical. The sole advantage of using CATV-DTV is the fact that a 70 cm ATV signal can be received directly on your home TV receiver simply by tuning to cable channels 57-61. As shown in Table II, a stronger rf signal is required compared to the other DTV modes. Early DTV amateurs did experiments with CATV, 64-QAM and found it would sometimes work in an over the air broadcast mode, but not reliably. It did not tolerate any multi-path, which is almost always present for terrestrial broadcasting. It is NOT recommended for ATV use.

ATSC: In the USA, in 1996, the FCC selected the Advanced Television Systems Committee's (ATSC) 8-VSB system for broadcast DTV in USA with a 10 year transition period from analog to digital. 8-VSB is an eight level digital amplitude modulation using vestigial upper sideband filtering. There was great controversy over this choice by the FCC. ATSC eventually was only adopted by the USA, Canada, Mexico and S. Korea. The rest of the world went with DVB-T which used COFDM modulation. In 1999 Sinclair Broadcasting challenged the selection of 8-VSB over DVB-T. Field tests showed the superiority of DVB-T for indoor reception with simple antennas. The FCC turned down the petition. An FCC report did however find that COFDM had better performance in both dynamic and high level static multipath situations and for mobile reception with doppler shift. It is not possible to receive ATSC 8-VSB in a moving vehicle. The new (2026) version of ATSC 3.0, which was recently approved by the FCC, will in fact use COFDM and is not backwardly compatible with the original ATSC-1.0. The majority of US TV stations recognized the superiority of COFDM and actually use it for their electronic news gathering and studio to transmitter links. While USA TV receivers receive ATSC 1.0, they do not tune the amateur 70cm band and to use them would require a down-converter. A few USA amateurs have experimented with ATSC, but most have dropped it in favor of either DVB-S or DVB-T. Today, (2026), only one ATV repeater in the USA is using ATSC. It is WD0GIV in New Orleans.

DVB-S: DVB-S stands for Digital Video Broadcasting - Satellite. It is the DTV standard for satellite TV broadcasting. It was designed to work in an environment with very weak signals and line-of-sight paths from the satellite direct to small earth dish antennas. DVB-S was not designed for a multi-path environment. DVB-S uses MPEG-2 video compression, Forward Error Correction and QPSK modulation. There is now (2026) also a newer improved version called DVB-S2. See Fig. 16. QPSK stands for Quadrature Phase Shift Keying. It is related to BPSK-31 which is commonly used by radio amateurs for digital text communications on the HF band. BPSK is simple binary phase modulation in which the phase of the transmitted signal is either 0° or 180°, which is the equivalent of simply turning a sine wave upside down.. For QPSK, the phase is rotated in 90° increments from 45° to 135° to 225° to 315°. The signal amplitude always remains the same, much like a CW or FM signal. QPSK is the most robust form of DTV modulation as it does not require any amplitude changes, much like FM in this regard.

The earliest amateur DTV work was done in the early 2000 time period and was done by hams in Europe using DVB-S. Their 70 cm band allocation was smaller than in the US and the best band for them was the 23 cm band. They started using DVB-S originally due to the availability of very inexpensive, Free-To-Air (FTA) satellite TV receivers which used an L-band (i.e. 1 - 2 GHz) IF and thus worked directly on the 23 cm band. As a result, most of the DTV activity in Europe is still using DVB-S and now S2. Also, in Europe they have a geo-stationary amateur satellite called QO-100 which supports ATV. It uses DVB-S with 13cm uplink and 3cm downlink. In the USA, there is presently (2026) one ATV repeater using DVB-S. It is the W6CX Mt. Diablo repeater serving northern California.

DVB-T: DVB-T stands for Digital Video Broadcasting - Terrestrial. DVB-T was specifically designed to work in the normal situation of an earth based transmitter broadcasting to home TV receivers in an environment where multi-path exists. The terrestrial signal path attenuation can be frequency dependent and can result in a very distorted received signal. The negative effects of multipath reflections are reduced, by using a modulation with a low effective bitrate per carrier. To reduce the effective bitrate per carrier, DVB-T spreads out the bitrate over a large number of carriers. This spreading out results in either 2,000 or 8,000 closely spaced carriers using COFDM. COFDM stands for Coded Orthogonal Frequency Division Multiplexing. DVB-T also includes pilot carriers scattered across the channel bandwidth. The receiver measures these known pilots and uses them to correct for the channel distortion. A "Guard Interval" is always included within each COFDM symbol. The Guard Interval is used to sychronize the receiver, i.e. same as sync pulses in NTSC. The Guard Interval can be adjusted from 1/32, 1/16, 1/8 or 1/4. A larger guard inteval implies a lower bit-rate efficiency and is thus a trade-off between bit-rate and network tolerance to echos and reflections. Forward Error Correction (FEC) is also included in the data overhead. FEC choices are: 1/2, 2/3, 3/4, 5/6 or 7/8. 1/2 means for every real data bit there is also a FEC bit, i.e.

100% overhead. 7/8 means for every 7 real data bits there will be one FEC bit. The result is a highly robust system of transmission which corrects for, and eliminates, multi-path in the image. The "Ghosting" of the old analog TV transmissions is completely eliminated.

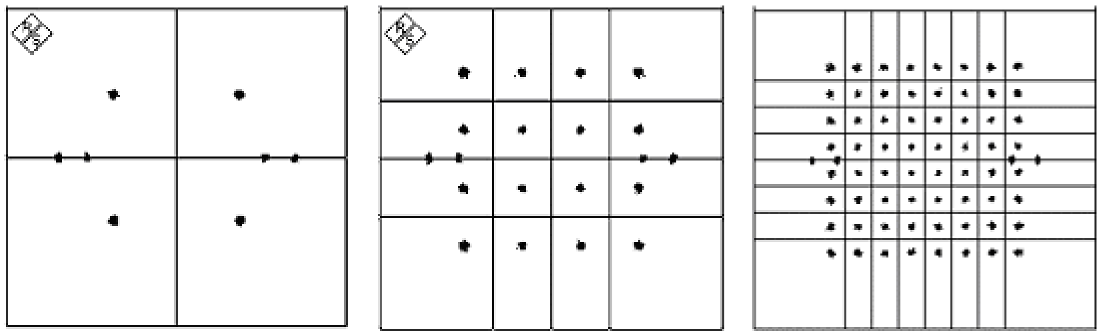


Fig. 16 DVB-T, I-Q Constellation Diagrams for QPSK, 16QAM AND 64QAM (left to right)

The DVB-T system supports three modulation methods of QPSK, 16-QAM and 64-QAM. See Fig. 14. 16QAM stands for sixteen state Quadrature Amplitude Modulation. Each quadrant of the QPSK, I-Q diagram is now divided further into four more sectors, for a total of 16 sectors. There now are three distinct amplitude levels. Because different amplitudes represent different logic values, 16QAM is thus more susceptible to degradation than QPSK, more like AM vs. FM.

A DVB-T receiver will automatically track and accept any of these methods. Table II shows that the weakest signal performance is achieved using QPSK. For amateur DTV, we do not have the luxury of having high power transmitters. We usually are running QRP levels of 10 watts or less. Thus to maximize our chances of success, we should restrict our DVB-T to QPSK. Higher data bit rates are possible with 16 or 64-QAM, but very acceptable, live action, high-definition, 1080P pictures are still possible with QPSK.

DVB-T usage for amateur DTV is of much more recent origin than DVB-S. It really started about 2012 when low cost, modulators became available from the Hi-Des company in Taiwan (www.hides.com.tw) Some USA ATV amateurs were early adopters and soon demonstrated it's superiority over the other DTV modulation modes. The original DVB-T system was designed for the standard broadcast TV channels of either 6, 7 or 8 MHz bandwidth.. Amateurs using the Hi-Des modulators more recently have been experimenting with much narrower DVB-T bandwidths down to 1 MHz. 6-8 MHz bandwidths support 1080P, high definition video and even several 480i programs within a single channel. Narrow bandwidths of 1 or 2 MHz and QPSK do not support high definition, but do support a very high quality, standard definition, 480i DTV signal. DVB-T with 2 MHz band-width & 16-QAM will support high definition. Most ATV repeaters in the USA which have transitioned to digital are using DVB-T.

If you, or your local club or ARES group, are thinking about getting into ATV, and in particular DTV, and if there is no other pre-existing ATV activity in your area, then my recommendation is for you to go with digital DVB-T as the best performing, most robust system for terrestrial DTV. Likewise if your group is presently using analog TV and wants to move up to digital, then go with DVB-T.

IP-TV: All of the previously discussed modes of TV have all been used for "Broadcasting". There is also another category of TV via RF using IP techniques on Wi-Fi. These will not be discussed here. There is a distinct difference in the two approaches. The IP approach is intended for peer-to-peer communications and thus requires that a two way link be established with "hand-shaking" before a TV signal can be passed. There must be both a transmitter and receiver at both ends of the mesh path. For video over a mesh network, a very reliable, almost error free, two way link must be established. It is not suitable for "broadcasting" a TV signal to cover a wide area and numerous, perhaps even many unknown viewers. IP-TV is more suitable for dedicated point-to-point links. For Broadcast TV, and ATV as discussed in this handbook, it is more like HF radio where we throw our signal out into the air and hope someone, somewhere can hear it. Successful transmission of broadcast TV is one way. Anyone with the proper receiver can receive it. A two way, hand-shake, rf path is not required.

Fig. 17 Set-Top box receivers for TV & USB dongle TV tuner

Chapter 7 RECEIVERS for ATV

For the reception of 70 cm, AM-TV, or VUSB-TV, or CATV-DTV, we already own a suitable receiver. The TV receivers sold in the USA include tuners for analog NTSC, digital ATSC 1.0 and CATV-DTV. In the cable TV mode, (not antenna), the cable channels 57 - 61 cover the amateur directly the amateur 70 cm band. The ATSC tuners, used in the "Antenna" mode, however typically do not cover the 70 cm band. A separate down-converter to a standard broadcast channel would be required.

The frequency coverage for all of these TV receivers is the broadcast VHF lo-band (Ch 2-6, 54-88MHz), VHF hi-band (Ch 7-13, 174-216MHz) and UHF (Ch 14-36, 570-608MHz). Plus the cable TV channels 2-158 with continuous coverage from 54 to 1002 MHz in 6 MHz TV channel spacing. Not all TV receivers will reach up to 1 GHz. It should be noted that the TV bands and channel widths vary with other countries. Broadcast TV channels are either 6, 7 or 8 MHz wide.

For any of the other TV modes, a separate receiver is required. Your home TV is then used strictly as the monitor to display the resultant audio and video. For analog TV, you would use the composite video (yellow RCA plug) and stereo, line level audio (Red & White RCA plugs). For digital TV, you will use the HDMI cable connection. The separate ATV receivers function in the same fashion as the set-top boxes supplied by many cable companies and satellite dish companies. If you are using DVB-S, then in all likely hood, you are actually using a FTA satellite receiver box.

DVB-T set-top boxes designed for the European consumer market are readily available at low cost on the internet. See Fig. 17. They work with bandwidths of 6, 7 and 8 MHz. However, some of them will not tune directly to the amateur 70 cm band, only the commercial broadcast bands. Hi-Des in Taiwan does make a DVB-T set-top receiver which covers all frequencies from 170 to 950 MHz, including the 2 m, 70 cm, 33 cm bands. and works with bandwidths from 2 to 8 MHz. The Hi-Des, DVB-T, set-top box receiver is shown as the top unit in Fig. 17.

COMPUTER TV: Another option as a TV receiver is to purchase a TV Tuner, USB dongle for your personal computer. See Fig. 17. For DVB-T this is a really low cost solution as they are available on the internet in the $10-$100 range. Most of these seem to use the same basic design with an R820T DTV tuner IC and an RTL2832U DVB-T COFDM demodulator IC with a USB interface. The most well known dongle for radio amateurs is the RTL-SDR.COM (www.rtl-sdr.com). The tuner's frequency range is specified to be 42 to 1002 MHz with a 3.5 dB noise figure. There are others available which go even higher in frequency. These same dongles have been used by amateurs as generic software defined radio (SDR) receivers for many other RF applications, such as a spectrum analyzer, with appropriate software. While this is a very inexpensive approach, it is not a simple KISS, turn-key, solution such as found with the purchase of a set-top box receiver. A PC computer, and attendant computer skills are required to use this approach. The software typically supplied with these dongles is a "teaser" which is disabled shortly after installing unless you purchase it. The general purpose video processing software called ***VLC*** (www.videolan.org) works great with these USB TV Tuner dongles. ***VLC*** is a free and open source cross-platform multimedia player. However, it has been reported that not all hams have been able to get it to work on their computer. A lot depends upon your version of Windows and getting the correct driver. Not all USB TV tuner dongles are equal. Receiver sensitivity tests were performed on several different brands and the results varied widely. A google search will turn up a very large selection of dongles. Care must taken in selecting the appropriate dongle to be sure it will work for your desired TV modulation mode.

Old vs. New Analog TVs: Newer model TV receivers all include a blue screen, video squelch circuit in their analog receiver. Thus you will never see a weak, snowy picture, such as the P0, P1 or P2 shown in Fig. 7. If you want to do weak signal, analog TV work, then it is a good idea to not throw away your old CRT, TV receiver. Another solution would be to purchase an old analog TV demodulator. These were used by the cable companies at their head ends and by the hotel industry to provide their own in-house video distribution system. They are identical in appearance to the CATV modulator shown later in Fig. 18.

SCANNING REQUIRED: Unfortunately, the designers of our modern analog/digital TV receivers and set-top boxes made the use of these receivers difficult for ATV viewers. They figured they only needed to do a one time, initial set-up, for your cable or broadcast viewing the first time you opened the shipping carton. Typically, you will need to perform an auto scan for the TV receiver to search each and every TV channel to attempt to locate your friend's ham TV signal. Not a simple process ! If the TV doesn't find it on it's scan, it will then lock out that channel from it's memory. Most all modern TV receivers do not allow us the ability of random access from our remote control to any arbitrary TV channel the way we used to do it with analog NTSC TV.

This means it is a major headache to get a TV receiver initially trained to receive an ATV signal. If you have your own ATV modulator, you can set it for each channel to be used and then train your own receiver. If you are just an ATV viewer, it means you typically will have to take your receiver to another local ATV ham who can train your receiver for you from his modulator's signal..

Using a TV Tuner / USB dongle and the program VLC is much easier to tune to any arbitrary frequency. It is the equivalent of "random access" on old analog TV receivers. In the VLC program, one simply enters the desired center frequency and bandwidth of the DVB-T signal.

Chapter 8 ATV TRANSMITTERS

Unlike HF radio, and 2 m / 70 cm FM radio, we do not have big name suppliers like ICOM, Yaesu, Kenwood, etc. for ATV equipment. What commercial gear we use typically comes from China and for the most part from unknown manufacturers. Their product lifetimes unfortunately are often measured in months ! Most other ATV suppliers are small "Mom & Pop" operations of dedicated ATV amateurs working from their basements, often on a part-time, or retirement basis. The last section in this chapter includes a list of suppliers of ATV equipment, including transmitters.

AM-TV: For many years, most ATV hams purchased their AM-TV transmitters from P.C. Electronics, Tom O'Hara, W6ORG (www.hamtv.com) Tom is now retired and no longer building nor selling transmitters. However, his old transmitters are still sometimes available on the used equipment market and at ham radio swap fests. Tom’s transmitters all used the basic approach shown in the block diagram of the previous Fig. 10. For hams interested in designing and home-brewing their own AM-TV transmitter, this is the easy route to take.

MODULATOR + AMPLIFIER: The typical approach today (2026) used for building most ATV transmitters is to use a separate Modulator with an rf output power in the milliwatt range followed by a high power rf amplifier to boost the rf level to many Watts of power. See the previous Fig. 12. The modulator could be for either analog of digital modulation as desired. There are several companies offering suitable RF amplifiers for ATV service. They are listed in Chp. 13 at the end of this handbook.

AM-TV Modulators:

In 2020, Burt, N7CS, discovered AM-TV transmitters from China under the brand HLLY. The model TVX-50 was evaluated and found to be suitable as a 70cm modulator. It would operate on cable channels 57-61 for the 70cm band. It's rf output power was 50mW. A google search shows that it is still available in 20026.

Fig. 18 Chinese AM-TV modulator

Google searching today (2026) on Amazon, E-Bay, etc. turns up a few more suitable modulators from China. See Fig. 19. These are all quite low cost < $50.

Simple Ch 3 / 4 *All channel, synthesized*

Fig. 19 More Chinese AM-TV modulators

For the amateur 70cm band, these modulators can be used directly. If one wants to do AM-TV on any higher frequency bands then an up-converter with a local oscillator and mixer with be required.

Fig. 20 CATV modulator

VUSB-TV Modulators: For VUSB-TV, the modulators built for the cable TV industry use in their head-ends were ideal. See Fig. 20. They are small modulator units designed to be mounted side by side in a 19" rack enclosure. They are frequency synthesized and cover all of the possible cable channels from 2-125 (54 - 806 MHz). They require +12Vdc & +5Vdc. The original cost was typically $225 or $125 for a single frequency unit. They produce an ideal VUSB-TV spectrum with >50dB rejection of the out of channel lower sideband.

Unfortunately, now in 2026 with the transition to commercial broadcast digital TV, these CATV modulators are now considered obsolete. With careful google searches, they can still be found on the used, surplus market.

Fig. 21 A 70 cm, 6 MHz bandwidth, inter-digital, band-pass filter. Shown with the top cover removed. S21 frequency response 10dB/div & 5MHz/div

BAND-PASS CHANNEL FILTER: One approach to building a VUSB-TV transmitter is to start with an AM-TV transmitter and use a 6 MHz, inter-digital, band-pass filter on it's output. See Fig. 19. Such filters can be purchased commercially, or built in your own workshop. Unfortunately, they can be quite expensive. The list of references includes one on how to design and build your own BPF.

Fig. 22 5.8GHz, FM-TV gear

FM-TV Modulators: With the transition to DTV, most commercial grade, FM-TV equipment has disappeared from the market. KH6HTV Video does still offer them for the 23cm band. The main exception now are cheap imported transmitter / receiver pairs intended for the use in the drone, FPV market and for the wireless distribution of in-house video, and available on the internet. Note: FPV stands for "First Person View" meaning it provides the R/C, drone pilot a live view from the cockpit. These are available for the part 15, unlicensed 900 MHz, 2.4 GHz and 5.8 GHz bands. Some are being marketed also for the 1200 MHz region and being marketed for "Ham" use. The ARRL and FCC have been clamping down on these because they also transmit illegally on frequencies outside of the amateur 23cm band. Specifications for these are virtually non-existent and rf power specs. are typically overly optimistic. Today, the most readily available equipment is for the 5.8 GHz band. These are found typically on the internet from Amazon, E-Bay, etc. A complete 5.8 GHz, FM-TV transmitter and receiver pair can be purchased for an amazingly low price of about $30.

DVB-S Modulators: There are quite a few choices for modulators. For "appliance" operators, there is professional grade equipment available, but at a high $$ cost. A goggle search on the internet will turn up a lot of sources, all quite expensive as they were intended for use in earth station uplink terminals for satellites, not terestrial use. In the amateur ATV community there has been considerable effort by some dedicated amateurs to develop lower cost, pc board level modulators which rely upon an external personal computer to do a lot of the necessary number crunching. A lot of the early DVB-S ATV work in Europe was done using PC based modulators. The British Amateur Television Club (BATC) developed several DTV modules and sells them to members via their web site https://batc.org.uk/ Their DVB-S transmitter is called the "Portsdown". More recently other, lower cost, SDR based pc boards have become available and are being used for DTV modulators. They include: the Analog Devices ADALM-PLUTS SDR and the Lime-Micro mini-LimeSDR (www.limemicro.com). One disadvantage of using a PC based approach is it is not easily transported for portable use, such as for ARES deployments in the field. It is more suitable for home based ATV stations.

For assistance in getting on the air with DVB-S, the best resource is the BATC in the U.K. In the USA, it is the Mt. Diablo Amateur Radio Club (www.mdarc.org) in California.

DVB-T Modulators: For DVB-T, a low cost, appliance style, KISS, solution does exist for ATV. The Taiwan company, Hi-Des offers a line of affordable modulators and receivers. Most of the ATV amateurs in the USA that are experimenting with DVB-T are using Hi-Des equipment.

Fig. 23 Hi-Des DVB-T Modulator

Hi-Des (https://hides.com.tw/index_eng.html) is focusing on the digital signage, in-house video distribution, FPV drone and amateur TV markets. Their equipment is frequency synthesized and offers continuous coverage from 100 MHz up to 2.5 GHz in some units. I recommend their model HV-320 Modulator. It costs $400 (2026). It is very simple to operate. The only controls on it are Up/Down push buttons for channel selection. Far simpler to operate than your 2 m HT ! The modulator does require a minimal amount of initial setup, mainly to program it with the desired TV channel(s).

Other digital parameters, such as Forward Error Correction (FEC) can also be adjusted. A windows program called *AV-Sender* is supplied for this purpose and connects to the modulator via a USB dongle cable. After programming, the external PC is no longer required to be connected. A computer is not required for the Hi-Des receiver. It is programmed using the supplied remote control. Most DVB-T equipment supports bandwidths of 6, 7 and 8 MHz, i.e. commercial broadcast standards. In response to requests from ATV hams, Hi-Des equipment also supports narrower bandwidths from 1 to 8 MHz. Hi-Des also offers great customer support via e-mail. The author highly endorses the Hi-Des equipment.

There are also several other companies offering DVB-T modulators for similar prices to Hi-Des. See chapter 13 for a list. However, Hi-Des is the only one to my knowledge offering bandwidths lower than the commercial standard of 6 MHz.

Fig. 24 A complete 70 cm, 3 Watt, DVB-T Transmitter. It consists of a KH6HTV Video, model 70-7B linear rf power amplifier, a Hi-Des model HV-320E modulator, and a Canon camcorder,

RF POWER AMPLIFERS for ATV: The requirements for rf power amplifiers for ATV depend upon the modulation mode used. However, there is one common requirement. The amplifier must be rated for 100% duty cycle, continuous service. While typical amateur voice communications are mostly receiving and intermittent transmitting, a typical ATV transmission can run for many minutes, to hours or days in length. Another common requirement is that it should be broad-band, preferably covering the entire ham band. With ATV, we tend to move around the whole band with our 6 MHz wide ATV channels. Tuned amplifiers tend to be too narrow-band for ATV service.

The least stringent requirement is for FM-TV. Here any amplifier can be used. Class C amplifiers are preferred for most efficiency. The FM amplifier is driven hard to full saturated output.

For AM-TV, or VUSB-TV, a linear amplifier is required. If the AM-TV operator is not concerned about chewing up spectrum, they often push their power amplifiers to their limits. Doing this does cause severe compression of the sync pulses, which is actually self-defeating as it impairs the receiver's ability to lock onto a weak TV signal. This was often overcome in the AM-TV modulator stage by adding a sync stretcher circuit to boost the amplitude of the modulating sync pulses. This technique was used in the older P.C. Electronics AM-TV transmitters.

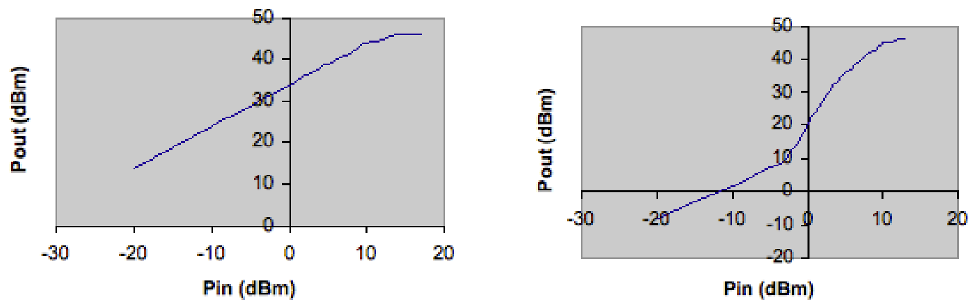


Fig. 25 Pout vs. Pin Transfer curve for a linear (left) & non-linear rf amplifier (right)

Aside from FM-TV, for all other ATV modes, both analog and digital, very linear amplifiers are required and they must not pushed to their limits. Driving an amplifier too hard and also the inherent non-linearity's in the amplifier itself result in creating distortion products which appear outside of the allocated TV channel. For VUSB-TV, this becomes very evident by the re-appearance of the lower sideband. It is most noticeable on the 3.58 MHz color and 4.5 MHz sound sub-carriers. An acceptable upper limit for amateur service VUSB-TV is to keep the lower sideband SSC at least 20dB below the upper sideband SSC. This is usually found by driving the sync pulse tips up to, but not beyond the -1dB gain compression point of the amplifier. A good, linear amplifier should have a straight line on it's Pout vs. Pin plot and then smoothly roll-over at the top as it reaches saturation. See the above plot in Fig. 25. RF amplifiers are typically rated for power output when this gain curve compresses by -1dB. The plot on the right shows an rf power amplifier which the author purchased from an amateur radio manufacturer who claimed it was suitable for ATV service. It definitely was NOT ! It would only have been useful for FM-TV service.

In DTV service, the quality of transmission is measured by Modulation Error Rate (MER). The ideal is to keep the MER better than 40dB. However, MER is very difficult to measure without sophisticated test instruments. Another easily measured indicator of DTV signal degradation is the presence of out of channel noise skirts. A typical DTV measurement that can be done by the amateur ATV operator, is the shoulder break point of these skirts on the rectangular pedestal of the DTV signal. This is typically measured with a spectrum analyzer. It could also be measured with a SSB receiver and the S meter. See the previous Fig. 15 for an example. For amateur DTV service, an acceptable compromise between maximizing the output power, acceptable MER, and minimizing out of channel spectrum pollution is to increase the rf drive level until the shoulder break point reaches -30dB. In commercial broadcast DTV, they drive their power amplifiers to about -28dB but then also add a sharp cut-off, band-pass filter to further suppress the skirts. Commercial DTV transmitters also use electronic pre-distortion, but the costs for this are beyond the range of the typical amateur budget. For amateur TV repeater service, we also will always add such a band-pass, channel filter. See Fig. 21.

For linear amplifiers, we can not use class C. They must be either class A or class A-B. Thus an ATV amplifier will be much less efficient than a class C amplifier. Earlier amplifiers used bi-polar transistors. Linear amplifiers for TV service and in particular DTV service today mainly use MOSFET transistors.

TV transmitters output power ratings are different depending upon the modulation mode used. For an FM-TV transmitter, it's output is constant and the amplifier is driven to it's max. saturated output. The FM transmitter is thus rated in terms of average, power. For an AM-TV, or VUSB-TV transmitter, it's average power output is variable and depends upon the gray level of the video signal being broadcast. It can vary by several dB. What is constant for this transmitter is the peak power of the TV sync pulses. Thus this transmitter is rated in terms of it peak power, i.e. PEP (Peak Envelope Power). This is the same as the rating on a SSB transmitter. For a DTV transmitter, there is no easily distinguishable feature, like a sync pulse. It's output is noise like. Being noise like it has very random peaks and valleys, but it can be characterized by an average power. Thus DTV transmitters are characterized by their rms average power. Depending upon the type of modulation being used the peak to rms average ratio might be from 8 to 12dB or more. Thus to avoid distortion considerable "Head Room" must be provided with a DTV transmitter. It should never be driven hard to push the average power any where close to the max. saturated output power limit.

As a typical example showing what can be expected in terms of output power, the following lists what is possible with the KH6HTV Video, model 70-7B amplifier (see Fig. 22). This amplifier uses MOSFET transistors. It's max. saturated output power for CW or FM service is 20 Watts (43dBm). It's -1dB gain compression point is about 10 Watts (40dBm). This is thus the PEP rating for VUSB-TV service. For DVB-T (QPSK) service, it is rated at 3 Watts, rms average (35dBm). This is at the -30dB shoulder break point. Thus for DTV service, a minimum headroom of at least 8dB is required.

Chapter 9 ANTENNAS for ATV

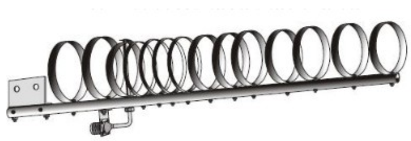
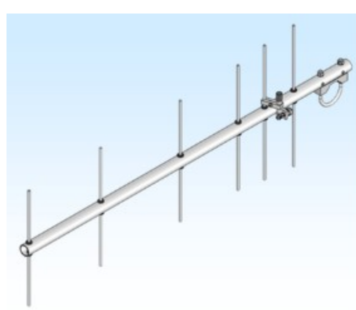




Fig. 26 Typical antennas used for ATV service, a 23cm loop yagi, a 70cm yagi, and a 5 cm parabolic dish antenna. -- insert a base station, omni-directional antenna & a flexible, "rubber-duck" antenna.

We use the same antennas as we use for other services. There is only one key criteria for selecting an antenna for ATV service. That is **BANDWIDTH** ! Because of the broad spectrum required for ATV, the antenna's bandwidth must be equally wide and preferably flat across the entire amateur band to allow flexibility in changing TV channels. There are quite a few suppliers of amateur band antennas. Unfortunately, specs. from many of them are vague and usually do not give any bandwidth information. Buyer Beware ! If the antenna manufacturer can not give you frequency information on gain and VSWR, especially vs. frequency, then you will need to rely upon recommendations from your ATV peers and antenna articles published in ATV magazines. For the 70cm band, for example, many of the really high gain yagi antennas were only designed to operate on the weak signal, SSB & CW, region right around 432 MHz. They had high gain, but narrow bandwidths. Many vertical, omni, base station antennas were designed specifically for the upper 10 MHz of the band (440-450 MHz) for use with FM voice repeaters. They worked well there, but very poorly at the bottom end of the band.

Polarization: To use horizontal or vertical polarization is always a major issue. Using the wrong polarization immediately results in at least a -20dB penalty. If there is already an active ATV group in your area, then the obvious choice is to use what they are using. Most of the weak signal, SSB & CW amateurs at 432 MHz are using horizontal polarization. Almost all FM voice repeaters are using vertical polarization. This is because it is far easier to make a vertical antenna for mobile use, hand-held transceivers and omni-directional repeaters. For ATV, there is not a standard polarization. Some ATV groups are using vertical while others are using horizontal.

Chapter 10 TV PROPAGATION

One of the first questions prospective ATVers always ask is "How far will my TV signal go ?" The best answer is "line of sight". Comparing the TV signal vs. an FM or SSB voice signal, using the same power levels, antennas, etc., the TV signal will not go near as far as the narrow band voice signal. This is set by the fundamental laws of physics. The limit is set by the noise floor of the receiver, which is a function of bandwidth. The thermal noise floor power is given by the equation $Pn = k*T*BW$, where k is Boltzmann's constant ($1.38*10^{-23}$), T is absolute temperature (290° K), and BW (in Hz) is the bandwidth. The amount of thermal noise power in a 1 Hz bandwidth is thus -174dBm. For various typical receiver bandwidths, the noise floor power is: -147dBm (500 Hz, CW), -140 dBm (2.4 kHz, SSB), -132 dBm (15 kHz, FM voice), and -106 dBm (6 MHz, TV). Any additional noise in the receiver, as measured by it's noise figure will raise further this noise floor. Thus, for TV we take an extra penalty of more than 20 dB over the performance of an FM voice signal.

For line of sight, UHF and microwave propagation, there also becomes the question of "Where is the radio horizon ?" If we lived on a flat earth, the answer would be infinity. Because we live on a spherical earth (radius = 6370 km), the curvature of the earth limits our horizon. It effectively puts a "hump" in the middle of our rf path. The line of sight horizon is set by pure geometry. Note this may not be your personal optical line of sight set by the resolution of your eyes, even using binoculars. The distance to the horizon is set by our observation height (or antenna height) above ground level. It is given by these equations:

$$\text{optical distance (miles)} \approx 1.23 * \sqrt{\text{height (ft)}}$$

The radio horizon is actually a bit further than the geometrical horizon. The refractive effects of the atmosphere cause a bit of bending in the radio waves and will push them typically about 15% further..

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

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

A few quick examples are: 5' => 3.2 miles, 30' => 7.7 miles, 100' => 14 miles. Adding antenna height at the receive site, we add the numbers for the two heights. For example transmitting from an automobile with an antenna height of 5 ft. to a remote base station with the antenna on a 30 ft. tower, the radio horizon = 3.2 + 7.7 ≈ 11 miles This calculation really only works over flat earth, not hilly or rolling terrain. On a large lake or the ocean, we do have such a flat surface. Obviously either putting up a higher tower or finding a high hill or mountain top works wonders. But of course, this is not news to us hams !

So after determining our radio horizon, the next issue to contend with is RF Path Loss. Path loss is the natural phenomena of radiating a certain amount of power but this power, again due to spherical geometry, gets spread equally over an ever expanding globe as it propagates away from the source. Thus the power density in watts/m^2 gets much smaller the further we get from the source. The formula for free space path loss based upon this geometry alone is:

$$\text{Free Space RF Path Loss(dB)} = 20 * \log10 (\text{f in MHz}) + 20 * \log10(\text{D in Miles}) + 36.6\text{dB}$$

Note in this equation the frequency dependency, For example, going from 70cm to 23cm bands we suffer about a 10 dB hit in path loss. The equation assumes the use of a 1/4 wave antenna. The frequency dependency is because the effective area of a 1/4 wave antenna is a function of wavelength. The shorter the wavelength, the smaller the effective area to capture an rf wave.

A few quick calculations will give you an appreciation of the importance of path loss. As an example, for the 70 cm band (430 MHz) we get: 0.1 mile => 69dB, 1 mile => 89dB, 10 miles => 109dB, etc.

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

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

As an example using this calculator, let's enter the parameters of a typical 70cm ham, analog TV station:

Transmitter Power = 5 watts (+37dBm) Cable Loss = 1dB each end
Yagi Antenna Gain = 11dBi each end
Desired Receiver Power = -65dBm (40 dB s/n, P5 for analog,VUSB-TV)

The calculator gives the answer of 43 miles for pure, unobstructed, free space, line of sight path. The theoretical results really only apply for outer space applications. In the real, terrestrial world, we encounter a lot of other obstacles and we would never achieve this ideal. In 2011 and again in 2016, several Boulder, Colorado area TV hams have run TV propagation field trials. Measurements were taken of the actual received signal strength in dBm. One observation that stood out was "Over very clear, line-of-sight paths, even with directional antennas, where multi-path was not a major issue, the actual path loss was typically 5 to 15 dB worse than the calculated, theoretical path loss." For obstructed paths, even more loss was typically encountered. Thus the likelihood of our ever experiencing just free space path loss is extremely rare.

The above equations were for ideal, unobstructed, line of sight situations. What can limit us in the real world ? Lots of things including: ground reflections, vegetation, tall buildings, urban building clutter, hills, ridge lines, mountains, etc. The absorption by vegetation, due to water content, goes up with increasing frequency. Getting over obstructions to our line of sight path involves diffraction which can introduce considerable extra dB loss. Most of the rest of the losses result from Multi-Path. This is reflected waves from other objects which arrive at the receive site later in time and can cause standing wave patterns in the receive signal which at certain frequencies might totally null out the desired direct path signal. Another perturbing effect can be "Doppler" shift due to moving objects disturbing the various multi-paths. A pure, free space, channel is called a "Gaussian". It is very rare in a terrestrial environment. If there is a direct line-of-sight path, but also multi-path signals arriving at the receive antenna, then this is called a "Ricean" channel. If there is no direct line-of-sight path, but multi-path signals arrive at the receive antenna, this is then called a "Rayleigh" channel. Each type progressively degrades the channel performance and leads to more path loss.

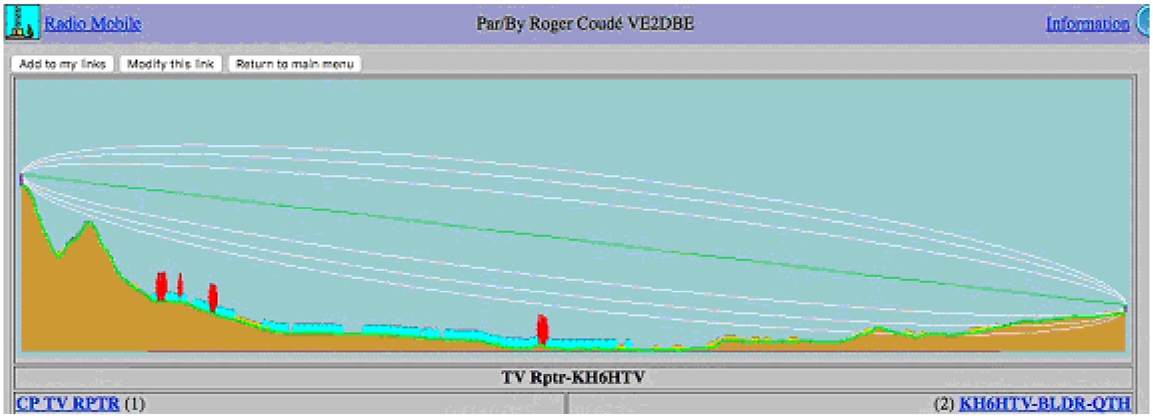


Fig. 27 Typical RF path profile generated by *Radio Mobile*. ATV repeater to KH6HTV QTH, 5.3 mile path shown.

RADIO MOBILE: There is an excellent free, on-line, computer program for calculating rf propagation in the real world. It is called *Radio Mobile* (http://www.ve2dbe.com/english1.html). This program was written and copyrighted by Rodger Coudé, VE2DBE. The free, on-line version is dedicated to amateur radio use and as such will only accept input frequencies in the amateur radio bands. The mathematical model is a mix of the Longley-Rice model, the two rays method, and the land cover path loss estimation. *Radio Mobile* first calculates the free space path loss. It then adds estimates for the excess path loss contributions from: Obstruction Loss, Forest Loss, Urban Loss, and Statistical Loss (typically always set to about 6.5dB).

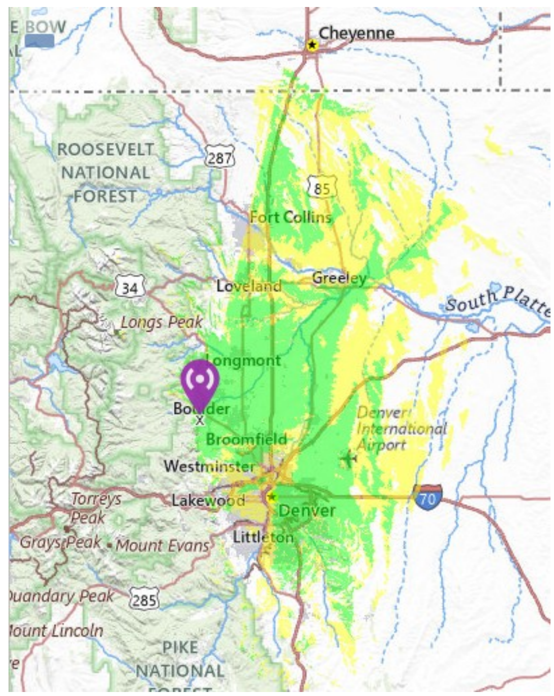


Fig. 28 Boulder, Colorado TV repeater coverage map generated by *Radio Mobile*.

Radio Mobile uses topographical information from Google Earth maps. *Radio Mobile* can calculate point-to-point rf path profiles and also wide area rf coverage maps. Comparing *Radio Mobile's* point-to-point predictions with the results from actual, mobile, field measurements of ATV signals has shown good agreement. The ATV repeater coverage maps also correlate well with the field measurements.

Fig. 27 shows a typical rf path calculation from *Radio Mobile*. For this particular example, Radio Mobile predicted that the received signal strength would be -50.3dBm. The actual measured signal strength was -51.5dBm, a difference of only about 1 dB.

Fig. 28 shows the rf coverage area of the Boulder, Colorado, 70cm, DVB-T repeater, as predicted by *Radio Mobile*. The yellow shaded areas are the "weak" signal areas with signal strengths of -90 to -80dBm. The green shaded areas are the "strong" signal areas with signal strengths > -80dBm. Actual mobile field surveys have verified this map. A DVB-T, DXpedition was made to the farthest point on the map. This was on the border between Colorado and Wyoming, near Cheyenne, Wyoming. The distance to the repeater was 77 miles. Successful two way QSOs were held on both 70 cm and 23 cm with DVB-T. The predictions of *Radio Mobile* were verified.

Chapter 11 TV REPEATERS

Fig. 29 A basic, 70 cm, 10 Watt, DVB-T, Television Repeater

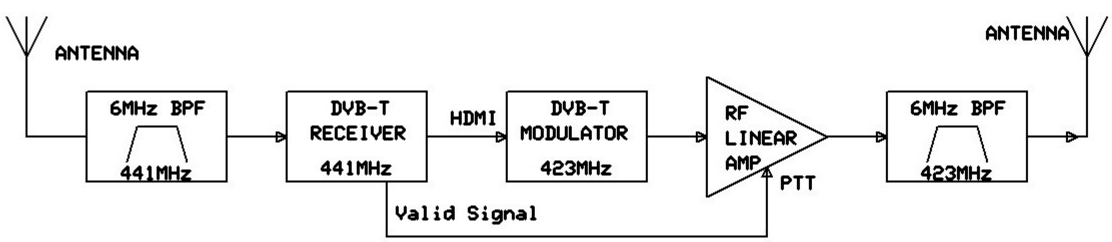


Fig. 30 A 70cm, Digital TV Repeater, Block Diagram

All amateurs are familiar with the use of FM voice repeaters. Practically every amateur radio club sponsors their own repeater either on the 2 meter or 70cm band. ATV groups also have TV repeaters. They are on typically the 70cm or 23cm bands and there are also some TV repeaters on the higher frequency, microwave bands. Most of the USA ATV repeaters have now transitioned over to digital TV. Many still retained their analog capabilities. See the list of references for a directory of the USA ATV repeaters.

The ARRL in their national band-plan for the 70cm band have designated Ch 60 (438-444MHz) as an input frequency and Ch 57 (420-426MHz) as the output frequency for ATV repeaters. Most USA ATV repeaters adhere to this band plan.

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

A basic ATV repeater usually consists of two antennas, one for receive and the other for transmit. A pair of very sharp cut-off band-pass, channel filters are required on both the receiver and transmitter to provide the required isolation to keep the transmitter's signal out of the receiver. The A/V output from the TV receiver is then fed into the TV transmitter. There also needs to be circuit to detect the presence of an incoming ATV signal. The analog TV repeaters used a form of tone squelch for recognizing an incoming TV signal to key the repeater. Instead of the typical sub-audible tone, they detect the presence of the 15 kHz horizontal sync pulse.

A basic TV repeater for DVB-T is actually quite easy to assemble. Fig. 30 shows the basic elements needed. It is far easier to build compared to a typical FM voice repeater, or an older NTSC, analog, TV repeater. Many of the elements needed for those repeaters are not needed for the DVB-T repeater. The basic elements required are just the DVB-T receiver, the DVB-T modulator and an RF linear power amplifier. This is all that suffices for a cross-band repeater, plus the appropriate antennas. However, if any other features are added to the repeater, such as multiple receivers, dual-mode, extra video sources, etc., then it becomes a very complex engineering project quickly.

A simple 70 to 23cm or 23 to 70cm, ATV cross-band repeater can be easily assembled using a single tri-band, (2m/70cm/23cm) mobile antenna and a tri-plexer (2m/70cm/23cm).

If assembling an in-band repeater, then Band-Pass Filters (BPF) are also required on the input and output. These BPFs need to be wide-band to match the channel bandwidth, in the usual case, 6 MHz. They also need to be low loss and have very steep skirts. Most TV repeaters are using inter-digital BPFs. discussed earlier, see Fig. 21.

Notice that the interconnection, in Fig. 30, consists simply of an HDMI cable between the receiver and modulator, coax cables for the rf circuits and one single logic data wire, called "Valid Signal", from the receiver to the power amplifier. If this is a local, manually controlled repeater, simply set up on the fly for an emergency situation, even this wire is not needed, just the control operator operating the power amplifier's On/Off switch. For automatic repeater operation, we do need the "Valid Signal" control line. Most DVB-T receivers include an LED front panel indicator showing when the receiver is actually receiving a valid DVB-T signal. The LED typically goes from red to green when a valid signal is received. What we thus need is to get inside of the receiver and pick off from the circuit board the LED drive signal and buffer it with a simple transistor circuit to provide an open collector to ground logic output. This is then used to connect to the Push-to-Talk (PTT) input on the rf linear power amplifier to key on/off the repeater's transmitter. Bingo at this point, you now have already easily assembled your own DVB-T television repeater ! ! !

FCC ID: OK, you say, "But what about meeting the FCC's requirement to identify the transmissions at least every 10 minutes ?." For ATV, the FCC accepts either a visual or audio ID. From your home station, this can be simply holding up your QSL card in front of the camera and/or making a voice announcement. For an analog TV repeater the repeater's call sign is usually superimposed on the video and/or with a Morse code ID superimposed on the audio. IDing is real SIMPLE with DVB-T ! ! With DVB-T, you are automatically identifying your signal, not every 10 minutes, but with every frame of video. Included in the digital data stream is a header of meta-data describing for the receivers, the modulation parameters used, including the call sign of the transmitter. Bingo, you have immediately satisfied the FCC's requirement to ID. Recall on today's TV sets, a simple push of the INFO button on the remote control puts up on the screen a display of the channel number, station call sign, resolution, and program description. This is from the meta-data header. However, to be on the safe side with the FCC, most DTV repeaters also actually switch into the video stream every 10 minutes, a separate video ID source with the station call letters.

TV Repeater Streaming: If you would like to see what other ATV groups are doing, it is now a simple matter to watch their video over the internet. The British Amateur TV Club (BATC) now offers an internet video streaming service from their server in the U.K. See Fig. 31. You do not need to be a member of the BATC to watch the video streaming. Go to their web site at: https://batc.org.uk/ Click on "Streamer". A/V streaming is available there from members and also member TV repeaters. You will find video there from ATV hams all around the world, primarily from the U.K. but also other countries, including the USA.

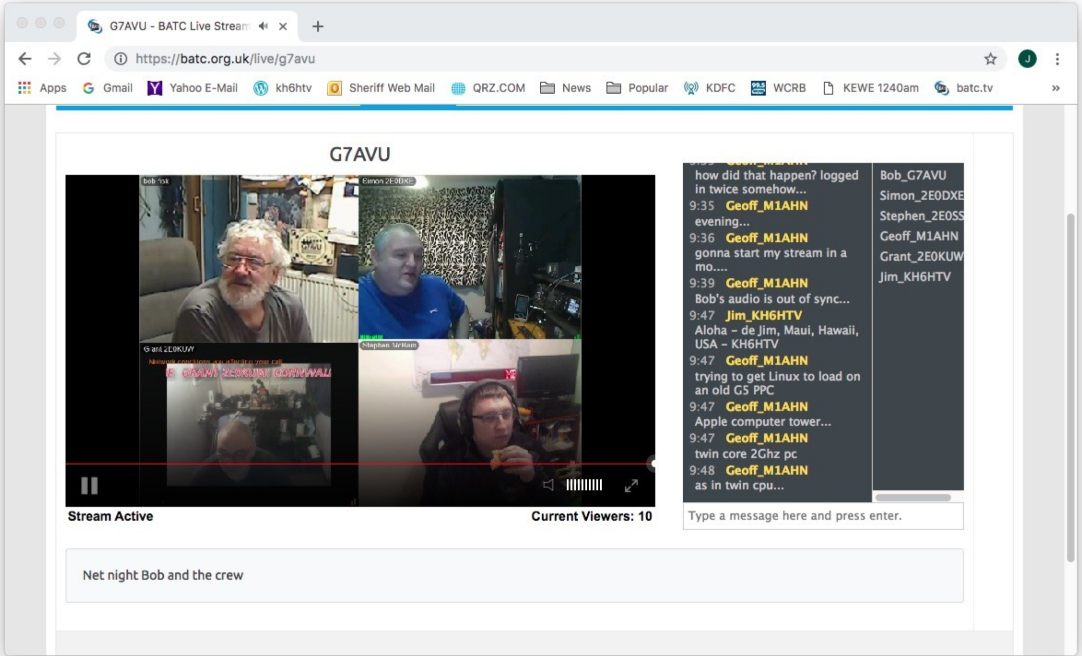


Fig. 31 An ATV live net - on the internet streamed from the BATC.

Chapter 12 - Amateur TV & ARES

Amateur TV, also called ATV, is an often overlooked communication mode which radio amateurs can offer in times of emergencies to our public safety agencies. RACES and ARES groups should strongly consider using ATV in addition to the more traditional radio services. In Boulder, Colorado, the local ARES group (BCARES) has been providing ATV for almost 35 years now. It is the most often requested BCARES service, far exceeding HF, VHF or UHF voice radio or packet radio. BCARES gets called several times a year by the Sheriff, Police and Fire depts. to provide ATV coverage of events ranging from forest fires, floods, political demonstrations, protest rallies, riots, SWAT operations, university football games, campus visits by VIPs, and large (50,000 runners) 10K races.

Fig. 32 BCARES live video feed on 70 cm ATV from mountain top to Boulder 911-EOC of slurry bomber fighting the Four Mile Canyon forest fire.

Fig. 33 BCARES TV camera crews at a University of Colorado football game using DVB-T, digital TV transmitters, as back-pack, pac-sets. left to right: George, KA0BSA, Steve, WB0NFQ, Jim, KH6HTV, Ron, K2RAS and William, KD0YYY

Fig. 34 Dave, KI0HG & Mark, KB0LRS, BCARES TV net control in the CU police chief's command post receiving four simultaneous, TV signals on channels 57-60 (70cm), from BCARES portable TV cameras/transmitters.

When BCARES initially started in 1991 with ATV, a single TV camera image was provided. It proved so popular with the police command staff, that they soon asked for even more cameras. This was first done on a single, 70cm, channel by switching on and off separate TV transmitters. Soon the police asked to see all the cameras at the same time. BCARES then drew the line at four cameras as we had run out of available 6 MHz channels in the popular 70cm band. BCARES used channels 57, 58, 59 and 60. This was a technical challenge to accomplish on four adjacent channels without co-channel interference. BCARES was then using AM-TV transmitters with an inter-digital, 6 MHz, band-pass filter on the output of each transmitter to produce VUSB-TV. BCARES also used identical channel filters on the inputs to each receiver. Initially, we provided the images on four separate TV receiver/monitors. However, these took up too much space in the command post. The next improvement was to build a Quad TV Receiver box.

Four separate, commercial grade, cable TV head-end receivers were used. The composite video outputs from these CATV receivers were then fed into a quad processor which combined the four video inputs into a single composite video signal with each image displayed in one of the four quadrants on a single video monitor screen. When desired, with the push of a button, a single image could be selected and displayed in full screen mode. See Fig. 31. This analog system was used successfully for many years by BCARES. In 2015, BCARES transitioned over completely to DVB-T, including assembling a new hi-definition, DTV quad receiver. They also added IP streaming capability to their receiver.

BCARES has it's own ATV equipment which it stores in the Boulder County EOC / 911 dispatch center for immediate 24/7 access. It also has TV receiving stations set up in the county EOC, police stations and also in police mobile command vehicles. For portable field operations, it uses a small, ATV transmitter, transported in a back pack, along with a camcorder, tripod, whip antenna and battery. The whip antennas are mounted along with the camcorder on the camera tripod. This maximizes their radiation efficiency. The DVB-T transmitters used are the same as shown in Fig. 23. Using a lithium battery, the camera and transmitter can be run for many hours at 100% duty cycle. BCARES has access to an ATV repeater, W0BTV, which covers the eastern, prairie half of the county. It also has a portable ATV repeater in it's equipment cache for use in the mountainous western half of the county. BCARES certainly serves as a role model for other ARES/RACES groups showing what can be accomplished with ATV for public safety.

Chapter 13 ATV SUPPLIERS

The following table lists known suppliers of ATV equipment. It is by no means complete. Many other suppliers can be found by google searching on the internet. Listing here does not imply endorsement by KH6HTV. The list is arranged alphabetically.

ATV Supplier	web site	Country	Notes
Advanced Receiver Research	www.advancedreceiver.com	USA	preamps
AMAZON	Www.amazon.com	All	Cameras modulators demodulators, A/V eqpt. Amps, etc.
Antennas-Amplifiers	Www.antennas-amplifiers.com	Serbia	Antennas, amplifiers
British Amateur TV Club	https://batc.org.uk/	U.K.	DTV kits -- free streaming service for ATV repeaters
Comet	www.cometantenna.com	Japan	antennas
CosmoWave	Www.cosmowave.net	Japan	Transverters, amplifiers, antennas, etc.
DCI (now Til-Tek Antennae)	www.dcifilters.com www.tiltek.com	Canada	RF filters and antenna
Diamond	www.diamondantenna.net	Japan	antennas
Digi-Key	Www.digikey.com	USA	Electronic components
Directive Systems	www.directivesystems.com	USA	VHF/UHF & microwave antennas
Down East Microwave	www.downeastmicrowave.com	USA	rf products from 50MHz to 10GHz, amplifiers, preamps, transverters, etc.
E-Bay	Www.ebay.com	All	Cameras, modulators, demodulators, A/V eqpt. Amps, etc.
GT-Media	Www.gtmedia.store	China	DVB-T & S receivers
Hi-Des	https://hides.com.tw/ index_eng.html	Taiwan	low cost DVB-T modulators & receivers
Hustler	Www.new-tronics.com	USA	antennas
ICOM	Www.icomamerica.com	Japan/ USA	Microwave transceiver with FM-TV
ID-Elektronik	https://www.id-elektronik.de/en/	Germany	Transmitters, Amplifiers, Antennas, Filters
Intuitive Circuits	www.icircuits.com	USA	OSD-ID board, DTMF decoder, analog ATV repeater controller board
KH6HTV Video	www.kh6htv.com	USA	70 & 23cm RF power amplifiers, preamps, up/down converters, BPFs - ATV/DTV application notes
KUHNE Electronics	https://shop.kuhne-electronic.com/kuhne/en/	Germany	power amplifiers, preamps, converters, oscillators, transverters
L-Com	www.l-com.com	USA	microwave antennas
Microwave Filter	www.microwavefilter.com	USA	filters
MiniKits	www.minikits.com.au	Australia	70cm, AM-TV & 1.2/2.4GHz FM-TV transmitter kits, rf amplifier kits
Mouser	Www.mouser.com	USA	Electronic components
M-Squared	www.m2inc.com	USA	antennas
OE7DBH	Www.oe7dbh.blogspot.com	USA	amplifiers
OREI	www.orei.com	USA	HDMI A/V accessories
P.C. Electronics	www.hamtv.com	USA	former supplier of AM-TV transmitters ATV application notes
PE1RKI	www.pe1rki.com	Holland	high power, microwave amplifiers, pre-amps, filters & antennas
Pro Video Inst.	Www.shop.provideoinstruments.com	USA	modulators

Sat-Link	www.sat-link.com.cn	China	modulators
SuperPass	www.superpass.com	Canada	microwave patch antennas
SV1AFN	Www.sv1afn.com	Greece	Amplifiers, filters, etc.
Taoglas	Www.taoglas.com	Japan	Band-pass filters
Technical Antennas	www.TechnicalAntennas.com	USA	antennas
THOR	Www.thorbroadcast.com	USA	modulators
Toner	Www.tonercable.com	USA	Analog & digital modulators & de-modulators
Q5 Signal	Www.q5signal.com	USA	Microwave transverters
W6PQL	www.w6pql.com	USA	high power amplifiers
WA5VJB	Www.wa5vjb.com	USA	antennas
Western Test Systems	www.westerntestsystems.com	USA	Microwave components

Plus the on-line resources of AMAZON, E-BAY, Alibaba, Banggood, etc. should be google searched for a lot of misc. ATV parts & accessories.

Chapter 14 REFERENCES

Additional material for subjects covered in this handbook.

Note: The references listed below are mostly all Application Notes from KH6HTV Video. They are available free, to be down-loaded as .pdf files from the web site: www.kh6htv.com -- click on "Application Notes" on the tool-bar.
References to TV Repeater's Repeater and ATV Journal are also available from www.kh6htv.com

Chapter 1 - Introduction
"Introduction to Amateur Digital Television", AN-45s, Aug. 2018, rev. Feb. 2021, 33 pages -- similar to this handbook, but devoted exclusively to DATV.

Chapter 4 - Amateur TV Bands & Frequencies
"70 cm & Microwave Amateur TV Frequencies", AN-10c, June 2022,, 5 pages

Chapter 6 - TV Modulation Methods
"Why VUSB-TV vs. AM-TV ?", AN-1, Sept. 2011, 3 pages
"DVB-T the Solution for Ham Digital Television", AN-17, July, 2014, 8 pages
"Why I Selected DVB-T for Amateur Digital TV", AN-25, Dec. 2015, 5 pages

Chapter 7 - TV Receivers
"How to Receive Amateur Digital, DVB-T Television Signals", AN-21e, Feb. 2021, 8 pages
"DVB-T Receiver Sensitivity Measurements", AN-29, June, 2016, 5 pages
“What Are the Differences in Receiver Sensitivity for 2, 4 & 6 MHz Band-Width DVB-T Signals ?”, BATVC TV Repeater’s Repeater, Sept. 2022, issue #110, pp. 5-7.

Chapter 8 - TV Transmitters

"Notes on Setting Up Hi-Des DVB-T Modulators & Receivers", AN-18e, Nov. 2021, 17 pages
"DVB-T Recommended Parameters", AN-39c, Jan. 2023, 10 pages
"Amplifier Output Power for Various Modulations", AN-46, Sept. 2018, 13 pages

Chapter 9 - TV Antennas
"Comparison Tests of Various 70 & 23 cm, Antennas for ATV" AN-67, Feb. 2023, 15 pages – also see AN-67 Ant. Notes & AN-67 RL

Chapter 10 - TV Propagation
"TV Propagation", AN-33a, Oct. 2016, 12 pages
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