Boulder Amateur Television Club

TV Repeater's REPEATER

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BATVC web site: www.kh6htv.com

ATN web site: www.atn-tv.com

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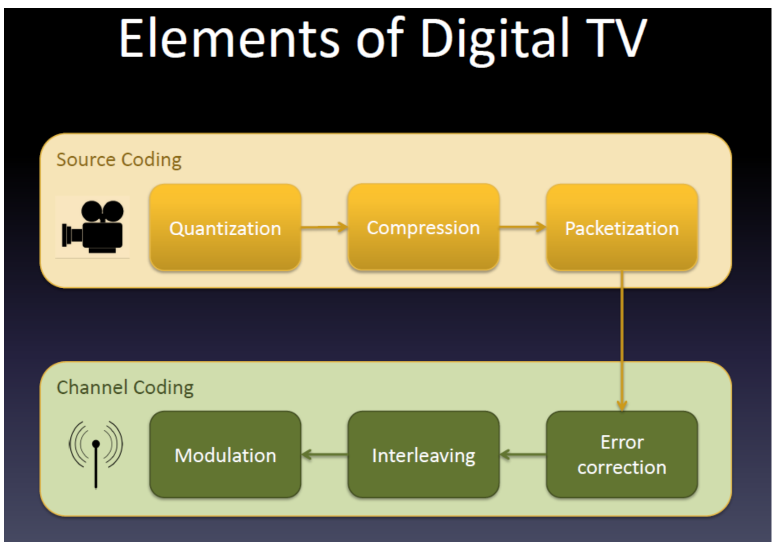


(from K0DVB)

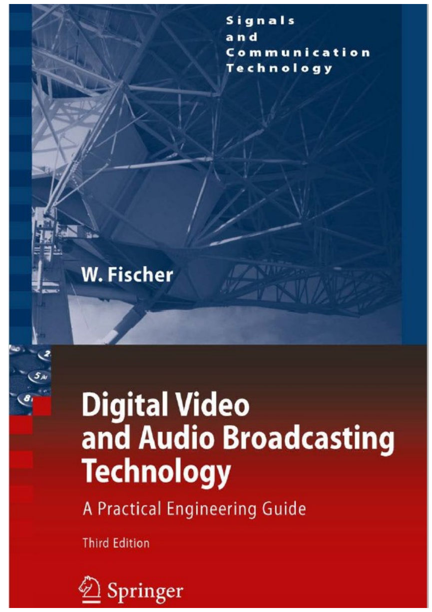
SPECIAL ISSUE on DVB-T Digital Parameters

Jim, KH6HTV

Note: several figures used in this article came from K0DVB, Matt Holiday's slide show talk given as ATV training classes to members of the Boulder, CO ARES (BCARES). https://k0dvb.org/ https://bouldercountyares.org/our-tool-bag/bcares-amateur-tv/

In our previous issue, #148, we discussed some experiments to demonstrate the effects of adjusting the various digital parameters for a DVB-T signal upon the ultimate weak signal capability of a receiver. So just what are these parameters ?

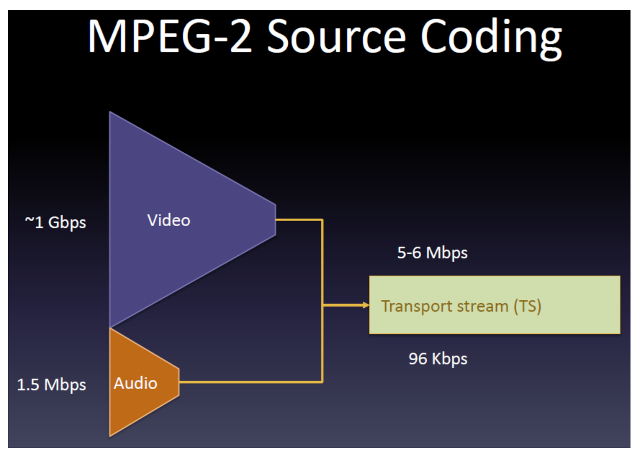
I consider the "Bible" for DTV. ------ *"Digital Video and Audio Broadcasting Technology --- A Practical Engineering Guide"* by Walter Fischer (TV engineer at Rhode & Schwartz, Munich, Germany). Springer, 3ed edition, 2010 Much of the material for this article comes from this book. I denote this material using quotes.



SOURCE CODING--MEDIA CONFIGURATION:

Video Encoding: For DVB-T, we have a choice of two methods, either MPEG2 or H.264.

"In 1992, MPEG-1 was created as the first standard for encoding moving pictures accompanied by sound. The aim was to achieve a picture quality close to that of VHS (352x288) at CD data rates (< 1.5 Mbit/s)." MPEG-2 then followed in 1996 with higher resolution, better quality, and supported transmission, not just data storage. Then in 2003 a still more improved system was released. It goes by several names, H.264, AVC (Advanced Video Coding) or MPEG-4, part 10. "Compared with MPEG-2, H.264 is more effective by a factor of 2 to 3 and thus allows data rates which are lower by a factor of 2 to 3, often even with improved picture quality."



(from K0DVB)

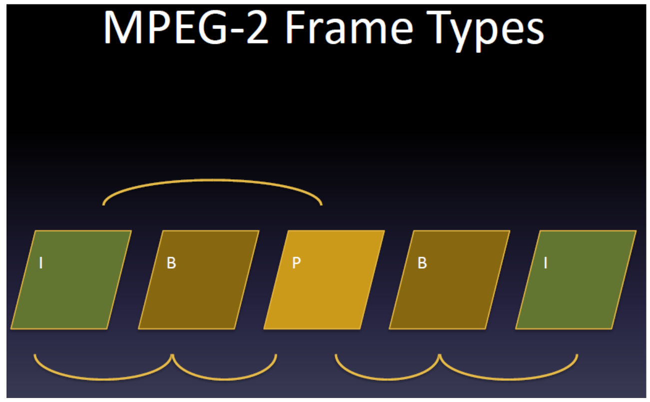
Video Encoding Resolution: With Hi-Des modulators, we have the ability to then select our desired resolution. They range from a low of 360x480 to a hi-def high of 1920x1080 pixels. For some other brands, this is not an option.

Max. Bit Rate: For Hi-Des, this is a user selectable value, while for some other brands it is fixed. It can never be set higher than a calculated theoretical maximum called the Modulation Data Rate. Hi-Des recommends it never be set any higher than about 80% of the Modulation Data Rate. This is to allow space for audio encoding and other over-heads. For very low RF band-widths, the percentage should be set considerably lower than 80%.

Video Aspect Ratio: This is the ratio of the screen width to height. Older TVs used 4:3. Newer wide screen TVs use 16:9.

Video Encoding Frame Rate: This is the number of video frames transmitted per second. We ususally try to adhere to the old NTSC (30 fps) or PAL (25 fps) standards.

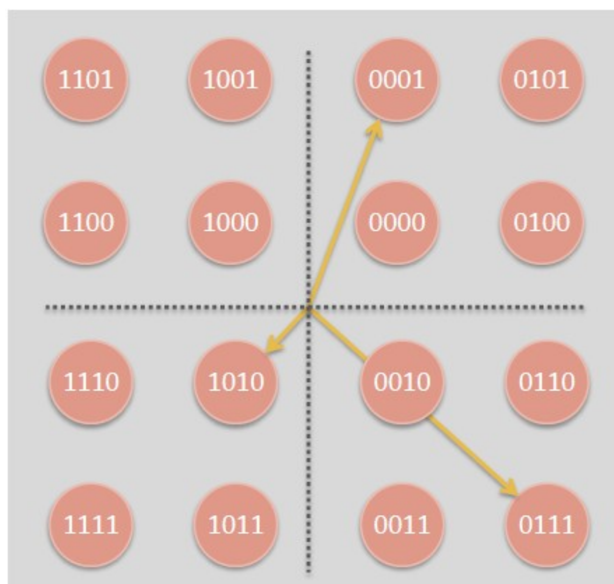
Video Encoding GOP Length: GOP stands for Group of Pictures. Successive frames of video are sent as various types of data. First there is the "I" or "Key" frame. It sends all the data required to create a complete picture in a frame. Each GOP begins with this "I" frame. The "I" is then followed by "B" and "P" frames which only send partial data, mainly dealing with motion compensated differences from the "I" frame. The GOP length parameter determines how many video frames are sent before starting over again with a new "I" - Key frame. Typical GOP length values are 30 or 60, i.e. every 1/2 second or full second.



(from K0DVB)

CHANNEL CODING -- TRANSMISSION CONFIGURATION:

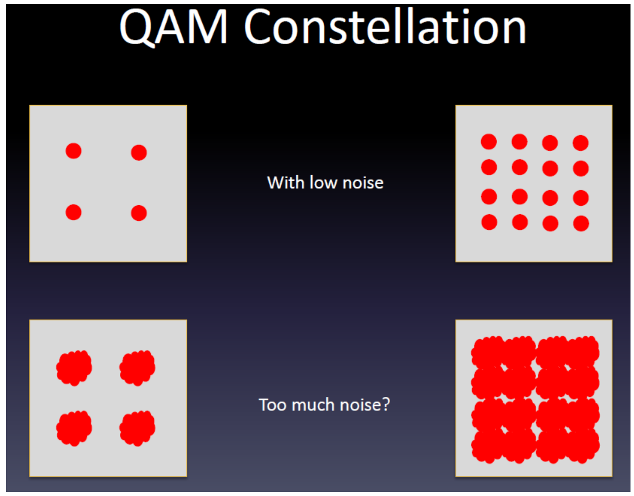
Modulation: The choices for DVB-T are: **QPSK**, **16QAM** or **64QAM**. QPSK stands for Quadrature Phase Shift Keying. It is similar to FM in that there is no change in the amplitude of the rf signal, only shifting of 90, 180, 270 or 360 (0) degrees of the phase. It is usually graphically displayed as a Constellation diagram with I & Q axis (I = in phase, Q = quadrature, or 90 deg). QPSK is the simplest with 4 possible logic states and 2 Bits/symbol. QAM stands for Quadrature Amplitude Modulation. It starts out with QPSK, but then adds discreate amplitude levels for higher amounts of logic. 16QAM adds 2 more amplitude levels of 25% and 75%. It is best shown in the I/Q constellation drawing to the right. It now has 16 logic states an 4 Bits/symbol. 64QAM adds even more amplitude levels with 64 logic states and 6 Bits/symbol. Using higher levels of QAM allows more data to be transferred within a fixed band-width rf channel. There will be some compromises required however to be discussed further. With the newer DVB-T2, they have added an even higher choice of 256QAM.



(from K0DVB)

Is QAM better than QPSK in a noisy rf channel ? What does this I/Q QAM picture tell you ? For the same amount of added rf noise to each logic state, we see that with 16QAM, the various logic states now are interfering with each other.

We reported some experimental results in our last ATV newsletter, issue #147 comparing these. 16QAM required a 6 dB stronger signal than QAM, while 64QAM required a 14 dB stronger signal. Clearly going to 256QAM with DVB-T2 would require an even stronger rf signal with attendent improvement in required S/N.



(from K0DVB)

# of Sub-Carriers: DVB-T uses a system called Coded Orthogonal Frequency Division Multiplex or **COFDM** for short. Basically it means the data is split up and transmitted over many sub-carriers. For DVB-T the choice is either 2K or 8K. Newer DVB-T2 adds more choices. For our USA standard 6 MHz TV channels, the sub-carrier spacings are: 840 Hz (8K) or 3.35 kHz (2K).

"Due to multi-path reception, fading occurs which is frequency- and location-selective. In terrestrial radio transmission, narrowband or wideband sinusoidal or impulse-type interferers must also be expected which can adversely affect reception. Plus Doppler shift in mobile operations." --- "Single carrier methods have a relatively high symbol rate, often within a range of more than 1 MS/s up to 30 MS/s. This leads to very short symbol periods of 1 μs and shorter (inverse of the symbol rate). However, multi-path echo delays can easily be within a range of up to 50 μs or more in terrestrial transmission rf channels. Such echoes would lead to inter-symbol interference between adjacent symbols or even far distant symbols and render transmission more or less impossible. An obvious trick would now be to make the symbol period as long as possible in order to minimize inter-symbol interference and, in addition, pauses could be inserted between the symbols, so-called **Guard** intervals. However, there is still the problem of the location- and frequency selective fading phenomena. If then the information is not transmitted via a single carrier but is distributed over many, up to thousands of subcarriers and a corresponding overall error protection is built in, the available channel bandwidth remaining constant, individual carriers or carrier bands will be affected by the fading, but not all of them. If, however, many thousands of subcarriers are used instead of one carrier, the symbol rate is reduced by the factor of the number of subcarriers and the symbols are correspondingly lengthened several thousand times from < 1 μs up to a millisecond. The fading problem is solved and, at the same time, the problem of inter-symbol interference is also solved due to the longer symbols and the appropriate pauses between them. It is now only necessary to see that the many adjacent carriers do not interfere with one another, i.e. are orthogonal to one another. Hence COFDM."

For DVB-T, there is a choice of using either 2K or 8K sub-carriers. Thus "the symbol lengths are either 250 μs (2K) or 1 ms (8K). The 2K mode has greater subcarrier spacing of about 4 kHz but the symbol period is much shorter. Compared with the 8K mode with a subcarrier spacing of about 1 kHz, it is much less susceptible to spreading in the frequency domain caused by doppler effects due to mobile reception and multiple echoes but much more susceptible to greater echo delays caused by doppler effects due to mobile reception and multiple echoes." DVB-T2 adds more choices of the number of sub-carriers.

Actually not all of the many thousand sub-carriers are dedicated to carrying our A/V data. DVB-T also contains: Inactive carriers with fixed positions, Contiuous Pilots with fixed position, Scattered Pilots with changing positions and Transmission Parameter Signalling (TPS) carriers with fixed positions. The TPS carriers represent virtually a fast information channel via which the transmitter informs the receiver about the current transmission parameters. The Pilot Carriers are used in the receiver for rf channel degradation effects estimation and subsequent correction to remove multi-path.

Guard Interval: The purpose of the guard interval is to introduce immunity to propagation delays, echoes and reflections, to which digital data is normally very sensitive. In OFDM, the beginning of each symbol is preceded by a Guard interval. As long as echoes fall within this interval, they will not affect the receiver's ability to safely decode the actual data, as data is only interpreted outside the guard interval. The guard interval is not left empty, but contains a fixed data pattern which helps the receiver acquire sync lock. In DVB-T, the choices for Guard are: 1/32, 1/16, 1/8 and 1/4 of the data symbol length.

Forward Error Correction - Code Rate: The previous parameters discussed concerned how the data was arranged in the COFDM signal to compensate for rf channel degradation. The Code Rate deals with adding Forward Error Correction (FEC) to help the receiver decode corrupted data. In DVB-T, the choices for Code Rate are: 7/8, 5/6, 3/4, 2/3 and 1/2. What this ratio means is how much of a symbol is devoted to real video data and how much is error correction info. For example 5/6 means a video data symbol is split into 6 pieces with 5 being real video data and the last piece being error correction data.

Channel Band-Width: The sizes of many other parameters are determined based upon how much frequency is allocated to the actual rf channel. In the USA, the standard TV channel band-width is 6 MHz. Standard TV channels vary from 5 to 8 MHz world-wide. 7 MHz in Europe being the most common. With the transition from analog TV to digital TV, these channel band-widths were usually retained. Radio amateurs have been recently experimenting with narrower band-widths. Hi-Des DVB-T equipment supports band-widths down to 2 MHz. An actual DVB-T signal does not occupy the entire channel allocated band-width. It is actually a bit narrower to allow some guard band for the steep skirts of the digital signal to roll-off to an acceptable lower dB level. For 6 MHz BW, DVB-T, the actual signal band-width is 5.71 MHz.

Modulation Data Rate: This is NOT a parameter which can be programmed by the user. Instead it is a theoretical, calculated value based upon the selection of all of the above transmission parameters. This is the number which should be consulted when setting the video encoding data rate. As an example for: 6 MHz BW, QPSK, 8K sub-carriers, 5/6 Code Rate, and 1/16 Guard Interval, the calculated Modulation Data Rate is 7.16 Mbps. Going from QPSK to 64QAM ups this to 21.96 Mbps.

AN-39 DVB-T Recommended Parameters

-- This app. note was written in 2017, but is still very relevant today. Therefore, I am re-printing it here in our ATV newsletter. It discussed some lab bench tests comparing various digital parameters, much like we recently repeated and reported in the last newsletter, issue #147. Of particular interest is the inclusion of some actual, in the field, mobile tests which compared results using both analog FM-TV, analog NTSC VUSB-TV, with DVB-T, and on both 70 cm and 23 cm bands.

Application Note
AN-39c
June, 2017
rev. Jan. 2021
rev. Nov. 2021
rev. Jan. 2023

DVB-T Recommended Parameters

Jim Andrews, KH6HTV

I am often asked what parameters are recommended for DVB-T, amateur, digital Television (DTV). The commonly used modulators, such as the Hi-Des model HV-100EH, HV-310 or HV-320E, allow a wide adjustment range in many of the parameters. The selection of the proper values can have a dramatic impact on the system performance. The table below lists my recommendations.

Common Parameters: *Media Configuration* = HDMI input, H.264 Video Encoding, CBR Data Rate Control, 29.97fps Frame Rate, 16:9 Aspect Ratio, 30 GOP Length, 0 B Frame Number,
MPEG2 Audio Encoding, 96Kbps Audio Encoding Rate, and HDMI HDCP = on
Transmission Configuration = 8K FFT, 1/16 Guard (sync) Interval
TS Info Configuration = PMT PID 0x640, Video PID 0x641, Audio PID 0x642, Service Name = your station's call sign

PARAMETER	Perfect Channel	Normal Channel	Poor Channel	Weakest Signal
Bandwidth	6 MHz	6 MHz	6 MHz	2 MHz
Modulation	16-QAM	QPSK	QPSK	QPSK
Resolution	1080P	1080P	720P	480i
lines	1920x1080	1920x1080	1280x720	720x480
Forward Error Correction (Code Rate)	5/6	5/6	1/2	3/4
Bit Rate	11.5 Mbps	5.5 Mbps	3.5 Mbps	1.2 Mbps
Receiver Sensitivity	-91dBm	-96dBm	-100dBm	-103dBm
with Pre-Amp	-94dBm	-100dBm	-104dBm	-108dBm

RECEIVER SENSITIVITY: The values reported in the table for receiver performance were measured at 423 MHz on a Hi-Des model HV-110, DVB-T receiver. The measurements were made in a controlled lab environment on a well shielded, closed coaxial circuit, using an HV-100EH modulator and calibrated coaxial fixed and step attenuators The modulator was located 75ft. away from the receiver to minimize any leakage signals. Thus the only effect altering the transmission channel was a progressively weaker, attenuated signal. There was no multi-path, RFI, etc. present to distort the signal. The pre-amp values were measured using an ARR model P432VDG amplifier (0.5dB NF, 18dB gain). Adding the low noise, pre-amp in front of the Hi-Des receiver improved the sensitivity by 3 to 5dB.

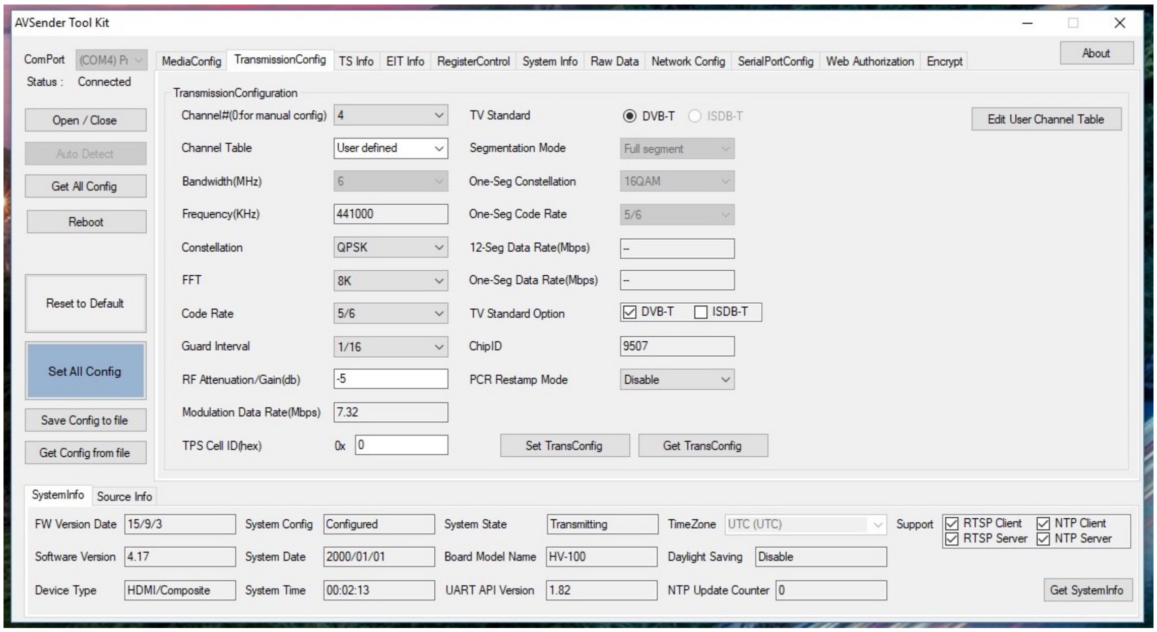


Fig. 1 Transmission Configuration page of *AVSender* --- shown with recommended settings for normal 1080P, 6 MHz BW, QPSK operation -- note: a custom channel table was used.

TRANSMISSION PARAMETERS: The parameters of Bandwidth, FFT, FEC and Guard Interval are extremely important in determining how well your TV signal will propagate and be decoded at the receiver under real world, multi-path conditions. These are set on the Transmission Configuration page of *AVSender*, Fig. 1. *AVSender* is the Windows computer program supplied by Hi-Des for setting the modulator's digital parameters. The normal bandwidth used is 6 MHz in the USA, which is the same as used by commercial broadcast TV stations. For extremely weak signal performance, going to the lowest possible bandwidth of 2 MHz with lower, 480i, standard definition resolution buys several dB in receiver sensitivity. The Constellation parameter selects the modulation method of either QPSK, 16QAM or 64QAM. The best video performance (in very strong signal conditions) is obtained using 64QAM and the highest possible bit rate. For weak signal, amateur useage, QPSK is recommended. Very acceptable, high-definition, video performance with normal scenes is obtained using QPSK. The Guard Interval is used to synchronize the receiver. It is the same as sync pulses used in the old analog NTSC system. The Guard ratio determines how much of the total data frame is devoted to "sync". The Code Ratio, also called FEC or Forward Error Correction ratio determines how much data is devoted to error correction, versus the true live video data. 5/6 FEC means for every 5 bits of real data, one extra bit is added for error correction. The FFT determines how many subcarriers are used within the channel bandwidth. The choice is either 2000 or 8000. (2K or 8K). I selected using an FFT of 8K based upon the recommendation in reference [1] which stated "An 8K system allows reception with longer multi-path echos." 2K is supposed to be a better choice for Doppler shift corrections for mobile operations. I have found that 8K works fine with mobile doppler shift at speeds of at least 75 mph.

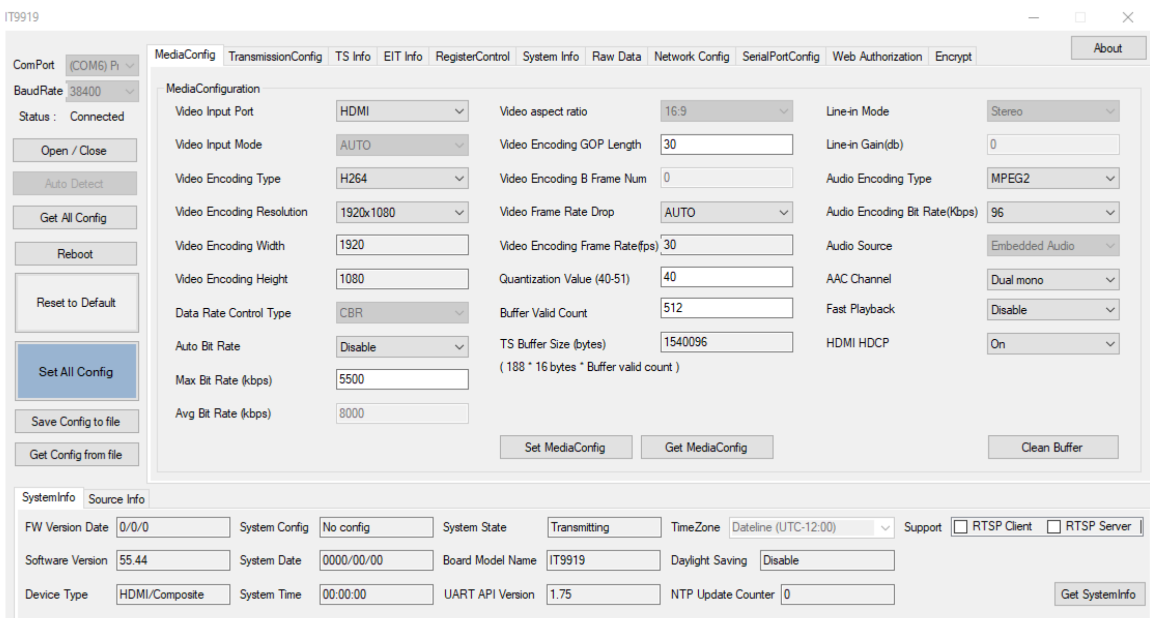


Fig. 2 Media Configuration page of *AVSender* --- shown with recommended settings for normal 1080P, 6 MHz BW, QPSK operation

MEDIA PARAMETERS: Another key parameter is the encoding data rate, called "Max Bit Rate." This is found on the Media Configuration page of *AVSender*, Fig. 2. To follow rapidly changing scenes, the highest possible data rate should be used. The max. theoretical possible data rate is a function of Bandwidth, modulation type, FEC and Guard Interval. Ref [2] tabulates all of the various possible options. *AVSender* also displays the theoretical maximum for any setting. It is on the Transmission page, Fig. 1, and called "Modulation Data Rate". It is grayed out indicating that you can not alter it. For a 6 MHz bandwidth, the theoretical maximum is 23.75Mbps for 64QAM with 7/8 FEC and 1/32 Guard Interval. For QPSK the maximum is a much lower 7.92Mbps with 7/8 FEC & 1/32 Guard.

The older Hi-Des HV-100EH will not operate above 16 Mbps. Trying to set any data rate too high, the Hi-Des HV-100EH defaults back to 8 Mbps. Thus there is not much to be gained by using 64QAM over 16QAM with the HV-100. The newer HV-320E does work with 64QAM at the highest data rate (suggest limit to 18 Mbps).

Caution: Operation at or near the theoretical maximum sometimes gave unacceptable breakups the picture. In their instruction manual, Hi-Des recommends that the "Max Bit Rate" be set no higher than

80% of the theoretical max. "Modulation Data Rate." The values listed in the above table are set approximately at 80%.

Another important parameter to be set is that of **HDMI-HDCP**. The HDMI protocol allows for motion picture copyright security to be implemented. Normally this prevents the use of certain HDMI equipment with others if copyrighted media would be compromised. This means that under some circumstances a video source such as a DVD player can only be connected to a video monitor and not a transmitter. If this parameter is set to OFF, you will not be able to connect a DVD player to your Hi-Des modulator. It will not accept the source and give you instead a screen with the test "No Input Video". It will only accept a TV camera input. To avoid this situation, you should thus set this HDCP parameter to ON. This does not mean it is thus OK or legal as an amateur to transmit copyrighted movies. But we may want to transmit our own DVD home movies, such as family events or travels. It is legal for us to do this.

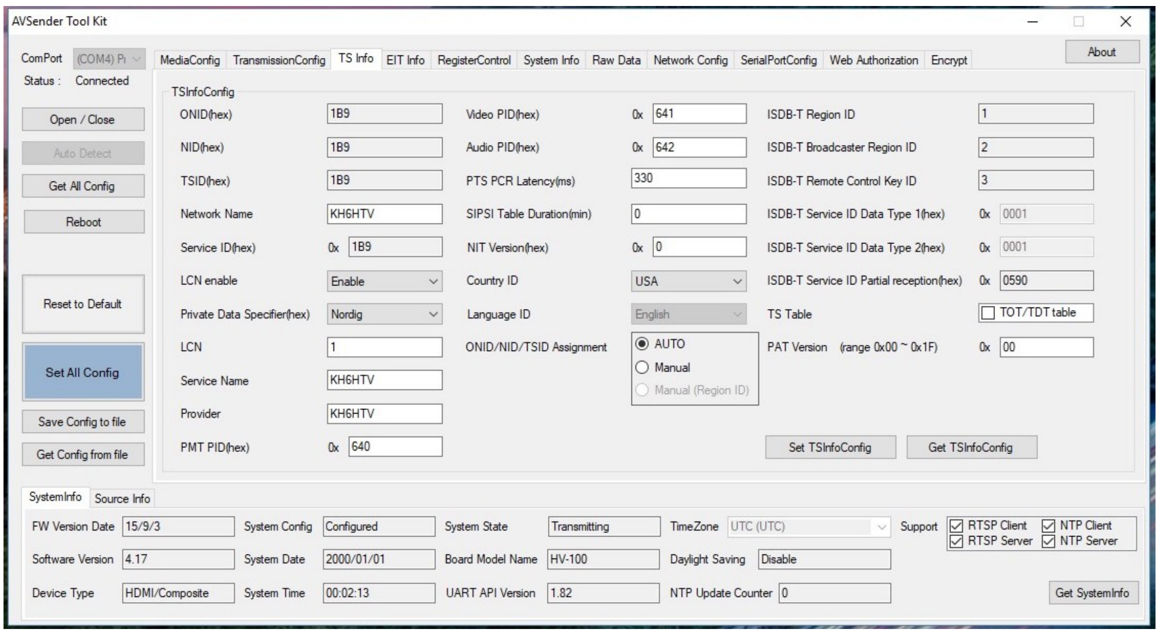


Fig. 3 TS Info configuration page of *AVSender*

TS INFO PARAMETERS: Don't change most of the parameters on this page, Fig. 3. The PIDs (Packet Identifiers) shown are the normal factory presets and normally shouldn't be changed. All DTV amateurs in your local area should use the same PIDs. If the PIDs of different stations do not match, the Hi-Des receivers will lock up when receiving a signal with different PIDs than those it was originally trained with.

Do however change the *Service Name*. Enter here your own stations's call sign. It will then be transmitted automaticaly with the data header and make your station IDing automatic to comply with FCC ID regulations.

NORMAL CHANNEL: Under normal conditions, to obtain the highest video definition possible of 1080P, a 6 MHz bandwidth is used. Most amateur operations are done with far lower rf power levels than commercial broadcast (watts vs. kilowatts !). Thus, the preferred modulation method is QPSK. QPSK gives considerable improvement in receiver sensitivity (-96dBm vs. -91dBm for 16QAM and -82dBm for 64QAM). 8K FFT was chosen to handle longer multi-path echos. I chose to use the factory presets of 5/6 FEC and 1/16 Guard Interval. Jim White, NC0JW, has confirmed that they are the same settings which CBS found in early DTV propagation experiments to work best in most situations [3]. These settings have been found to give very acceptable video performance for most all, but the very, fastest moving sports scenes.

POOR CHANNEL: For marginal channel conditions, with either weak signals and/or severe multipath(s), operation with the "Normal" parameters will be impossible. Oftentimes, perfect P5 video/audio can again be achieved by lowering the video resolution and using much more aggressive forward error correction. High definition, 720P, performance can still be achieved with very good picture quality. Using the much more aggressive FEC than for the Normal channel resulted in a 4dB improvement in receiver sensitivity for a multi-path free, closed circuit channel. Even better sensitivity improvements have been observed in real world, over the air conditions. A test run by Colin, WA2YUN, and Jim, KH6HTV on 23cm, DVB-T using loop yaggi antennas on a clear, line of sight, 5.6 mile path showed an impressive, 10dB improvement in weak signal reception using the 720P, 1/2 FEC over the 1080P, 5/6 FEC parameters.

2 MHz BANDWIDTH: In many parts of the USA, in particular large metro areas, there is too much other RF activity on the amateur 70 cm band to allow use of the full, broadcast standard, 6 MHz bandwidth. The Hi-Des modulators and receivers are capable of operating at much lower bandwidths, down to 2 MHz. Hi-definition, 1080P resolution does not work well at 2 MHz BW, QPSK. However, excellent video performance with standard definition, 480i is possible at 2 MHz BW, even using very aggressive FEC. Going to a lower bandwidth also buys us a considerable increase in receiver sensitivity (-108dBm, 0.9µV with a pre-amp). High definition, 720P, is possible at 2 MHz BW however using 16QAM or 64QAM.

DVB-T RECEIVERS: Fortunately, the available receivers are smart and do not need to be retrained when most of the transmitter's digital parameters are changed, even on the fly. As long as the center frequency, bandwidth and PIDs remain unchanged, the receiver will automatically track changes in parameters such as Constellation, FEC, Guard ratio, FFT, etc.

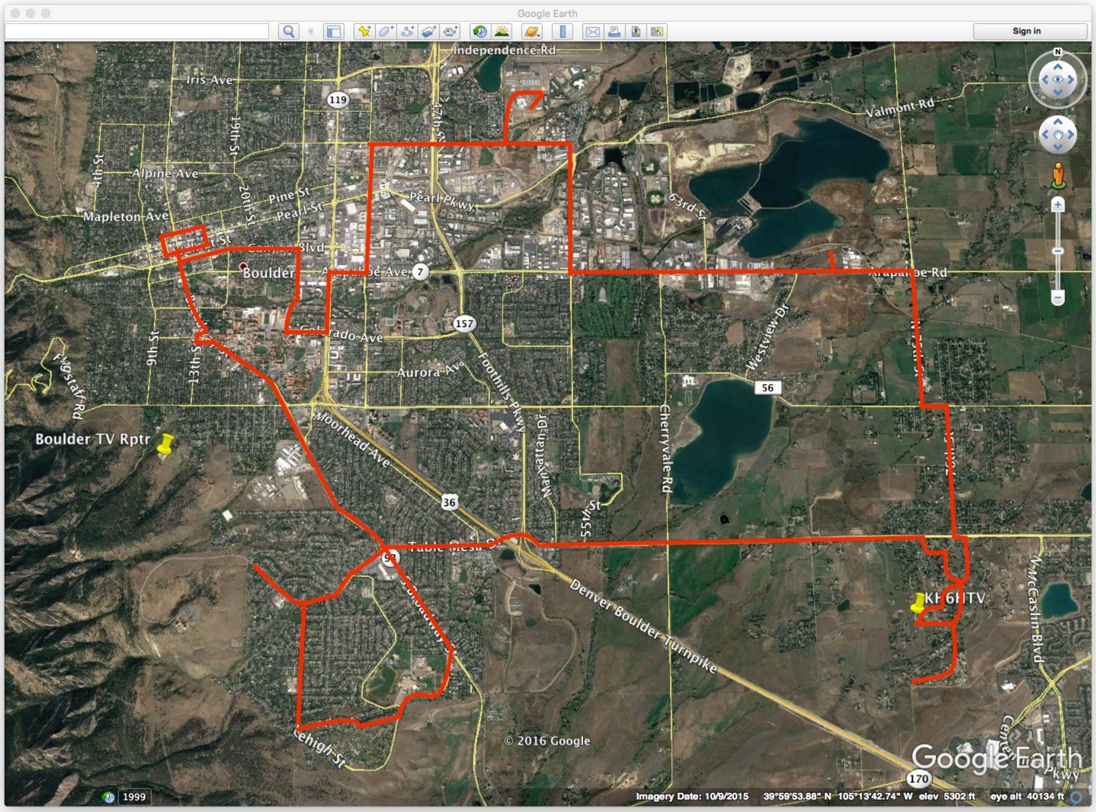


Fig. 4 TV Repeater Field Survey Route through city of Boulder & Boulder Valley

FIELD TESTS: In May and June, 2017, several Boulder, Colorado ATV amateurs did a series of field tests to compare various TV modulation methods, including DVB-T. Hams participating were: Don, N0YE, Colin, WA2YUN, Jack, K0HEH and Jim, KH6HTV. The Boulder TV repeater, W0BCR, was used. It is capable of receiving on both 23cm and 70cm bands. On 23cm, it receives either 6 MHz bandwidth, DVB-T, or 4 MHz deviation FM-TV. On 70cm, it receives either 6 MHz bandwidth, DVB-T, or 6 MHz bandwidth, NTSC, VUSB-TV. The repeater's ability to receive TV signals on all of these modes/bands was tested in controlled experiments. For DVB-T, the 1080P, 5/6 FEC and 720P, 1/2 FEC modulation parameters were tested and compared.

The first tests were performed by driving a mobile TV transmitter on a fixed, 30 mile route, Fig. 4. A camera was set up on a tripod in the passenger seat looking out the front windshield giving a live view of the current location of the transmitter. A TV receiver at the qth of KH6HTV was monitoring the relayed video from the TV repeater and it was recorded permanently on a DVD for later review and analysis. Also during some of the tests, N0YE and WA2YUN monitored the TV repeater's relayed images.

For the tests, the mobile transmitters and antennas used were very comparable for both bands. The digital, DVB-T, transmitters and the 23cm FM-TV transmitter all put out about 3 Watts (+35dBm). The 70cm, VUSB-TV transmitter put out 10 Watts (PEP). The mobile transmit antenna was a Diamond, tri-band, model NR-2000NA with 9 dBi gain on 70 cm and 7 dBi on 23 cm. The TV repeater's receive antenna, a Diamond X6000A, had essentially the same gain of +7 dBi on both 70 cm and 23 cm. There was a 14 dB difference between 23cm vs. 70cm tests, which consisted of the 10 dB extra path loss, 2 dB difference in transmitter antenna gains and about 2 dB additional coax feedline loss.

Fig. 4 shows the route driven for each of the six tests in the city of Boulder and the surrounding Boulder valley. This was almost a 30 mile route and typically took about 1 3/4 hours to traverse. The route chosen included rural, residential, urban canyons (among tall buildings), light industrial, open rolling hill prairie, high ridges, wooded areas, flat highways for high speeds (55mph), etc. It included several areas where BCARES has operated in the past for major police operations including the University of Colorado campus, Uni-Hill district, downtown Boulder, etc. Also included were the QTHs of several active ATV amateurs. The farthest distance tested from the repeater was about 6 miles.

CONCLUSION: In summary, the following list prioritizes the overall performance of the six, various modes/bands tested from best to worse.

1. 70cm, digital, DVB-T, 720P resolution, 1/2 FEC aggressive digital parameters.
2. 70cm, digital, DVB-T, 1080P resolution, 5/6 FEC, normal digital parameters
3. 70cm, analog, VUSB-T, 480i resolution
4. 23cm, digital, DVB-T, 720P resolution, 1/2 FEC, aggressive digital parameters
5. 23cm, analog, FM-TV, 480i resolution
6. 23cm, digital, DVB-T, 1080P resolution, 5/6 FEC, normal digital parameters.

Fig. 5 below shows an example of the video images received and recorded on DVDs for later review. This example was retrieved from three separate field test runs at the same identical location, but with different different modulation methods of FM, VUSB and DVB-T. At this particular location, the transmitter vehicle was shielded from the repeater by the highway overpass and berms.

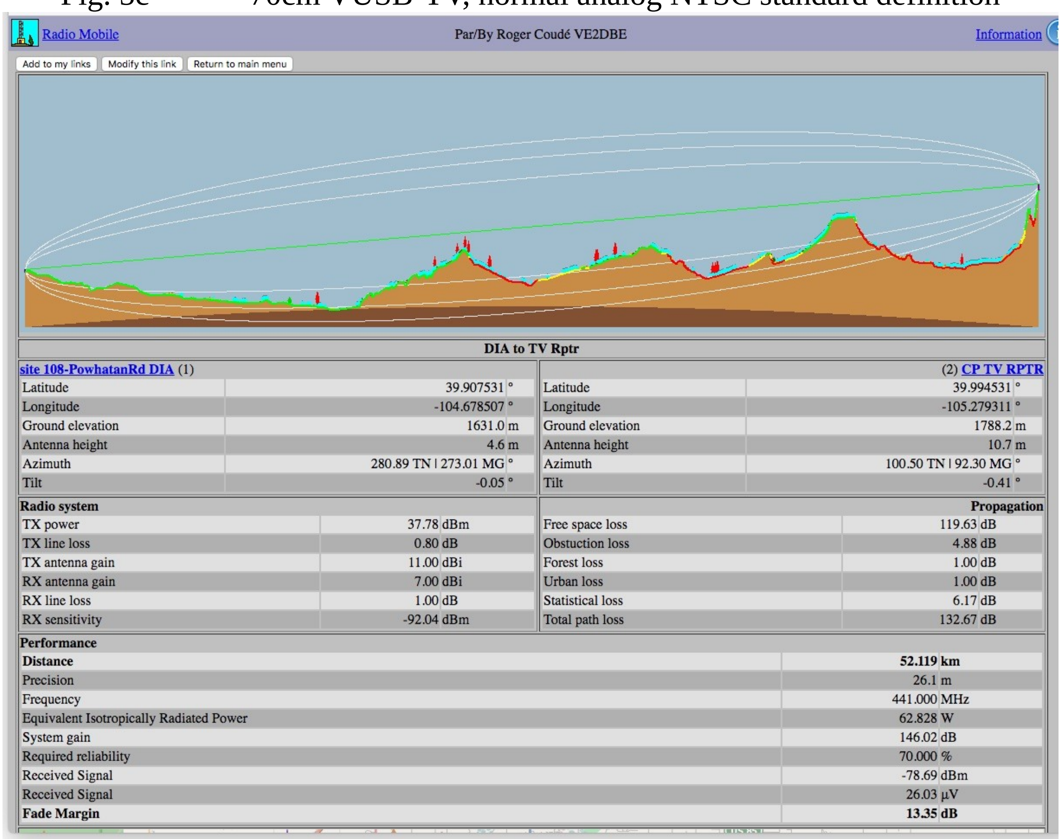
Clearly, the best performance was found using DVB-T on the 70cm band with a lower 720P resolution and the best possible, most aggressive, Forward Error Correction (FEC) of 1/2. Perfect P5 reception by the repeater was achieved from well over 90% of the total 30 mile route tested.

None of the other modes/bands came anywhere close to this performance. The 23cm coverage was particularly poor with coverage from much less than 30% of the areas tested.

Fig. 5a 23cm DVB-T with aggresive coding of 720P and 1/2 FEC

Fig. 5b 23cm FM-TV, 4 MHz deviation, 480i standard definition

Fig. 5c 70cm VUSB-TV, normal analog NTSC standard definition



DIA to TV Rptr

site 108-PowhatanRd DIA (1)		(2) CP TV RPTR	
Latitude	39.907531 °	Latitude	39.994531 °
Longitude	-104.678507 °	Longitude	-105.279311 °
Ground elevation	1631.0 m	Ground elevation	1788.2 m
Antenna height	4.6 m	Antenna height	10.7 m
Azimuth	280.89 TN I 273.01 MG °	Azimuth	100.50 TN I 92.30 MG °
Tilt	-0.05 °	Tilt	-0.41 °

Radio system		**Propagation**	
TX power	37.78 dBm	Free space loss	119.63 dB
TX line loss	0.80 dB	Obstuction loss	4.88 dB
TX antenna gain	11.00 dBi	Forest loss	1.00 dB
RX antenna gain	7.00 dBi	Urban loss	1.00 dB
RX line loss	1.00 dB	Statistical loss	6.17 dB
RX sensitivity	-92.04 dBm	Total path loss	132.67 dB

Performance	
Distance	**52.119 km**
Precision	26.1 m
Frequency	441.000 MHz
Equivalent Isotropically Radiated Power	62.828 W
System gain	146.02 dB
Required reliability	70.000 %
Received Signal	-78.69 dBm
Received Signal	26.03 µV
Fade Margin	**13.35 dB**

Fig. 6 *Radio Mobile* RF path prediction from DIA site to TV repeater

DIA TESTS: In June, N0YE and K0HEH drove out to the Denver International Airport (DIA) to perform repeater coverage tests from a remote, fringe area where BCARES might be called upon in the future for an airplane crash disaster. Fig. 6 shows the computer predicted, 70cm, rf path profile for the tests from DIA to the Boulder TV repeater, using the on-line program *Radio Mobile* [4]. The path was clear, unobstructed, line-of-sight over rolling prairie, but over a long distance of 32 1/2 miles. The 70cm predicted path margin was 13dB. They tested both 23cm and 70cm bands and all modes. For DVB-T, they only used 720P, 1/2 FEC. They used yaggi antennas (11dBi on 70cm & 18dBi on 23cm) on a telescoping mast. They were able to put perfect P5 pictures (except P3+ for 70cm, VUSB-TV) into the repeater from antenna heights of at least 10ft. They were unsuccessful with a mag. mount mobile, tri-band,NR-2000NA antenna.

REFERENCES:

1. "Digital TV - DVB-T", http://digitaltvbooks.com/cofdm.pdf
2. "Digital Video and Audio Broadcasting Technology - A Practical Engineering Guide", W. Fischer, Springer-Verlag, Berlin & Heidelburg, DE, 3ed Edition, 2010, ISBN 978-3-642-11611-7
3. Jim White, NC0JW, retired KCBS rf broadcast engineer, private conversation 10 July 2014.
4. "TV Propagation", Jim Andrews, KH6HTV Video Application Note, AN-33a, Oct. 2016.

Note: Revision "A", Jan. 2021 -- only change made was lowering the bit rates in table 1, page 1 to agree with Hi-Des recommendation they be no higher than 80% of max.

Revision "B", Nov. 2021 -- added comments about HDMI-HDCP.

Revision C, Jan. 2023 -- added info about HV-320E, corrected table I for weak signal FEC from 1/2 to 3/4

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FEEB-BACK:

Digital Parameters: Thanks for sharing your test results with the Hi-Des gear. I may do some more "tweaking" of our parameters based on your results. As some one said, "What a difference a dB can make." 73/Happy Thanksgiving, Mel, K0PFX, St. Louis, MO

Nostalgia: Another excellent newsletter Jim! I especially enjoyed your reminisces about the early days of fiber optic communications. I think that was about the time I was pushing modulation format up to 90 state QPR and stuffing 45 Mb/s (T3) data into a 10 MHz FCC allocation at 6 GHz. It was sure frustrating back then but thinking back now it was also a lot of fun.

Aloha, Alan AD6E / KH6TU, Maui, Hawaii

Laser Comms: Jim, I really love this newsletter. Did I ever mention that I've also been working with LASER Diode transmitter/receivers there in Panama City, Florida ? I like that BATC and So Cal are also doing it. One of the things I'd like to do now that I'm up and running on AREDN is to be able to use LASER for short range field deployments for disaster sites and events. This would be the ticket for our Mesh Chat, PBX systems, our mailbox servers "WINLINK" and for live streaming or video cameras. I've been at it for right at 5 years and I get a good amount of pointers and assistance from Mike Collis in LA. Didn't know if you mentioned my name, call sign and location would help to bring more interest in this High Speed communications. Feel free to mention me in any article or news letter. Hope your Thanksgiving was a great one.

73 de Wolfgang, KV4ATV, Panama City, Forida

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W0BTV Details: **Inputs:** 23 cm Primary (CCARC co-ordinated) + 70 cm secondary all digital using European Broadcast TV standard, DVB-T 23cm, 1243 MHz/6 MHz BW (primary), plus 70cm (secondary) on 441 MHz with 2 receivers of 6 & 2 MHz BW
Outputs: 70 cm Primary (CCARC co-ordinated), Channel 57 -- 423 MHz/6 MHz BW, DVB-T Also, secondary analog, NTSC, FM-TV output on 5.905 GHz (24/7 microwave beacon).
Operational details in AN-51c Technical details in AN-53c. Available at: ***https://kh6htv.com/application-notes/***

W0BTV ATV Net: We hold a social ATV net on Thursday afternoon at 3 pm local Mountain time (22:00 UTC). The net typically runs for 1 to 1 1/2 hours. A DVD ham travelogue is usually played for about one hour before and 1/2 hour after the formal net. ATV nets are streamed live using the British Amateur TV Club's server, via: ***https://batc.org.uk/live/*** Select ***ab0my or n0ye***. We use the Boulder ARES (BCARES) 2 meter FM voice repeater for intercom. 146.760 MHz (*-600 kHz, 100 Hz PL tone required to access*).

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