DVB-T Recommended Parameters

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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 or HV-102E, 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, 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

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>Perfect Channel</th>
<th>Normal Channel</th>
<th>Poor Channel</th>
<th>Weakest Signal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bandwidth</td>
<td>6 MHz</td>
<td>6 MHz</td>
<td>6 MHz</td>
<td>2 MHz</td>
</tr>
<tr>
<td>Modulation</td>
<td>16-QAM</td>
<td>QPSK</td>
<td>QPSK</td>
<td>QPSK</td>
</tr>
<tr>
<td>Resolution</td>
<td>1080P</td>
<td>1080P</td>
<td>720P</td>
<td>480i</td>
</tr>
<tr>
<td>lines</td>
<td>1920x1080</td>
<td>1920x1080</td>
<td>1280x720</td>
<td>720x480</td>
</tr>
<tr>
<td>Forward Error Correction (Code Rate)</td>
<td>5/6</td>
<td>5/6</td>
<td>1/2</td>
<td>1/2</td>
</tr>
<tr>
<td>Bit Rate</td>
<td>12 Mbps</td>
<td>6 Mbps</td>
<td>3.5 Mbps</td>
<td>1.2 Mbps</td>
</tr>
<tr>
<td>Receiver Sensitivity</td>
<td>-91dBm</td>
<td>-96dBm</td>
<td>-100dBm</td>
<td>-103dBm</td>
</tr>
<tr>
<td>with Pre-Amp</td>
<td>-94dBm</td>
<td>-100dBm</td>
<td>-104dBm</td>
<td>-108dBm</td>
</tr>
</tbody>
</table>

**RECEIVER SENSITIVITY:** The values reported in the table for receiver performance were measured at 423MHz 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 usage, 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 Hi-Des HV-100EH will not operate above 16Mbps.  Trying to set any data rate too high, the Hi-Des HV-100EH defaults back to 8Mbps.  Thus there is not much to be gained by using 64QAM over 16QAM with the Hi-Des equipment.  Operation at or near the theoretical maximum sometimes gave unacceptable breakups first in the audio and sometimes in 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%.
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. The KH6HTV Video, model 70-14 receiver does not have this problem.

Do however change the Service Name. Enter here your own station's call sign. It will then be transmitted automatically 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 echoes. 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 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 70cm 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. 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).

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 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, NOYE, 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, NOYE 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 9dBi gain on 70cm and 7dBi on 23cm. The TV repeater's receive antenna, a Diamond X6000A, had essentially the same gain of +7dBi on both 70cm and 23cm. 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 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 aggressive 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 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: