Application Note
AN-20a

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DVB-T DX-pedition

Jim Andrews, KH6HTV

Fig. 1 The ultimate proof ! Live, high-definition, 1080P, image received by N0YE in Boulder, Colorado from KH6HTV in Cheyenne, Wyoming.

SUMMARY: 10 Watt, 70cm, DVB-T signal successfully transmitted over 77 miles using conventional Yaggi Antennas.

In 2011, the first attempt at long distance amateur Digital Television (DTV) DX in Colorado was made by a group of Boulder hams [1 & 2]. The hams participating were: Don, N0YE, Jack, K0HEH, Roger, K0IHX, Bill, K0RZ, and Jim, KH6HTV. They operated on the 70cm band and were using CATV 64-QAM modulation. Jim drove to Cheyenne, Wyoming and set up a portable transmitting station with a 5 watt signal and a 6 element yaggi antenna. A successful one-way contact was made back to Boulder, but it was only possible due to Bill using his giant Moon-Bounce antenna array (+27dBi gain) with very low noise (0.3dB NF) preamp mounted on the antenna. Bill reported a receive margin of 7dB for the 75 mile path from Wyoming to his QTH.

In 2014, the Boulder TV hams discovered DVB-T, the European standard for Digital Video Broadcast - Terrestrial [3]. They have found for over the air transmissions, DVB-T far outperforms the CATV 64-QAM modulation, particularly in terms of receiver sensitivity and tolerance for multi-path. During the summer and early fall, Boulder TV hams have been performing numerous experiments to test the limits of DVB-T

propagation, both on the 70cm band and also the higher amateur radio microwave bands. Until now, all of these experiments were confined to the Boulder valley.

In October, the Boulder TV hams decided that we now needed to repeat the Wyoming to Colorado DTV experiment of 2011, but to see if we could now make it work using conventional, yaggi antennas, instead of a giant moon-bounce antenna array. This time, we wanted the stations to be the same as ordinary TV hams might use. Hams participating this time were: Don, N0YE, Jack, K0HEH, Roger, K0IHZ and Jim, KH6HTV. Both Roger and Don's QTHs are in excellent radio locations, situated on ridge lines just south of the city of Boulder with excellent views to the north towards Wyoming. Roger is at: 39° 58' 21", 5650 ft. Don is at 39° 58' 08" W x 105o 15' 06" W, 5675 ft. Jack and Roger pooled their equipment at Roger's QTH. Both stations were using Hi-Des model HV-110 DVB-T receivers along with yaggi antennas and low-noise preamps for receiving. They were also equipped with Hi-Des model HV-100EH DVB-T modulators and rf linear power amplifiers for transmitting.

On October 28th, Jim, KH6HTV, drove north to Wyoming and set up his 70cm, DVB-T transmitter at the same identical location as used in 2011. (41° 2' 53" N x 104° 53' 26" W, 6,265 ft. elevation). His portable station consisted of a Hi-Des model HV-100EH DVB-T modulator driving a KH6HTV Video model 70-9A linear power amplifier outputting 10 Watts avg. (+40dBm) on channel 58 (429 MHz) with a 6 MHz bandwidth. (*see Appendix I for all parameters*). He used a KLM, 6 element yaggi antenna (+11dBi) on a 10 ft. mast with a short, 15 ft. length of 1/2", low loss (< 0.3dB), semi-flex coax cable. The ERP was thus about +51dBm. For receiving he also used a Hi-Des, model HV-110 receiver and a low noise (0.8dB NF) ARR model P432VDG preamp plus a Haier 7" color LCD receiver/monitor. For video sources, he used a Canon hi-def, 1080P, camcorder with HDMI output and also a portable DVD player playing a continuous looping DVD slide show outputting a 480i composite video signal. While driving north from Boulder, Jim transmitted a continuous beacon signal from his car using the DVD player as the video source. While in motion, he used a Diamond model NR2000A, mobile whip antenna (+6.5dBi) on a Diamond mag. mount with a 15ft. cable (-1.5dB loss). Thus the mobile ERP was approximately +44dBm.

RESULTS: While Jim was driving north from Boulder, the hams back in Boulder were able to receive his mobile DVB-T signal reliably out to about 8 miles and intermittently out to about 25 miles. No mobile flutter was noted up to the maximum speeds traveled of 75 mph. From the Cheyenne site, only Don, N0YE, was able to receive a DTV picture and audio. Don inserted a calibrated Weinschel 1dB/10dB step attenuator in his antenna feed line ahead of the preamp and determined that his receive margin was 6dB with a measured DTV signal to noise ratio of 11dB. Without the preamp, his receive margin was only 1dB ! Without the preamp, the Hi-Des receiver's on-screen display of received power level and signal to noise ratio read -91dBm and 11dB respectively. Adding the 16dB gain preamp, the values were -75dBm and s/n = 13dB. The photographs in Figs. 1, 5 & 6 were taken by N0YE of the pictures he was receiving from KH6HTV in Cheyenne.

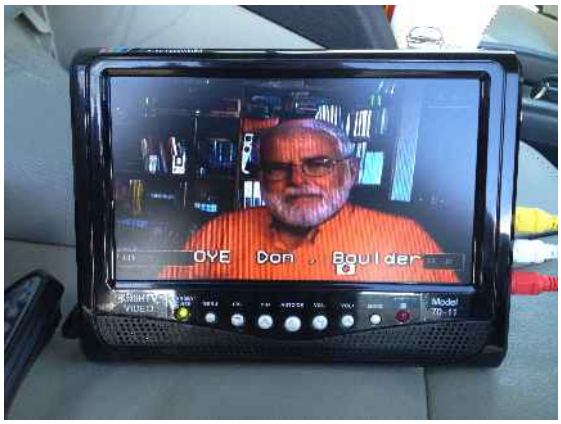

Fig. 2 N0YE's live, 70cm, DVB-T transmission from Boulder as received by KH6HTV in his automobile at the Mead AT&T microwave site on I-25. 24 mile distance, 19dB receive margin.

After the successful transmission of DVB-T from Cheyenne to Boulder, we next attempted to transmit DVB-T the other direction from both KHIHX's and N0YE's QTHs. These were unsuccessful. We also attempted to make contact on 23cm using both DVB-T and FM-TV with 3 Watt (+35dBm) transmitters. These attempts were also unsuccessful. On the way back to Boulder, Jim also set up operations at an AT&T microwave relay station on I-25 near the Mead exit (40º 14' 36" N x 104º 58' 47" W, 4980 ft.). Over this 24 mile path, N0YE and KH6HTV were able to establish reliable (+19dB margin), two-way, DVB-T QSOs on 70cm. See Fig. 2 above.

THEORY: So, how did our results compare to theory ? See AN-7a, reference [4] for a discussion of the relevant propagation theory. The key equations are as follows:

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

RF Path Loss(dB) = 20 * log10 (f in MHz) + 20 *log10(D in Miles) + 36.6dB

The total distance was 77 miles and the frequency was 429 MHz. Thus, the theoretical, free space, RF Path Loss would be 127 dB.

Fig. 3 N0YE's 70cm Yaggi antenna looking north towards Wyoming.

The 12 element Yaggi receive antenna, Fig. 3, was built by N0YE from the K1FO design in the ARRL handbook. Don estimates that it's gain was about +12dBi. Don's antenna feedline coax loss was about 3.2dB. The transmit, KLM, 6 element yaggi antenna, Fig. 6, gain was measured to be +11dBi [5]. Thus, putting all of these numbers in the above equation, the predicted Receiver Power would be:

Rcvr Pwr (theory) = +40dBm - 0.3dB +11dBi - 127dB +12dBi - 3.2dB = -67.5dBm

Measurements made on the Hi-Des model HV-110 DVB-T receiver showed it had a sensitivity of -97dBm, or -100dBm when used with a low noise preamp [3]. However, these measurments were done in a closed circuit environment with no multi-path present. Don measured a receive margin of 6dB when using his preamp. This would imply that the received power was probably -100dBm +6dB = -94dBm, whereas the Hi-Des receiver reported -91dBm, only a 3dB difference. While theory predicted -67.5dBm at the receiver, we actually encountered an additional -24dB of path loss. The Cheyenne to Boulder path was a nearly ideal path with no intermediate obstructions as shown by the path profile calculated by Google Earth, Fig. 4. The 24dB of extra path loss was consistant with earlier DVB-T propagation experiments on shorter paths.

References: (note: KH6HT Video application notes available at: www.kh6htv.com

1. "New Digital TV DX Record", Jim Andrews, QST, May, 2012, pp. 88-89.
2 ."Digital TV DX Record for Colorado", Application Note AN-11, KH6HTV Video, Nov. 2011
3. "DVB-T, the Solution for Ham Digital Television", Application Note AN-17, KH6HTV Video, July. 2014
4. "TV Propagation & Multi-Path Effects", Application Note, AN-7a, KH6HTV Video, Oct. 2012
5. "Antennas for Ham TV", Application Note, AN-4, KH6HTV Video, Sept. 2011
6. "Notes on Using Hi-Des DVB-T Products with KH6HTV Video -- RF Linear Power Amplifiers", Application Note AN-18, Oct. 2014

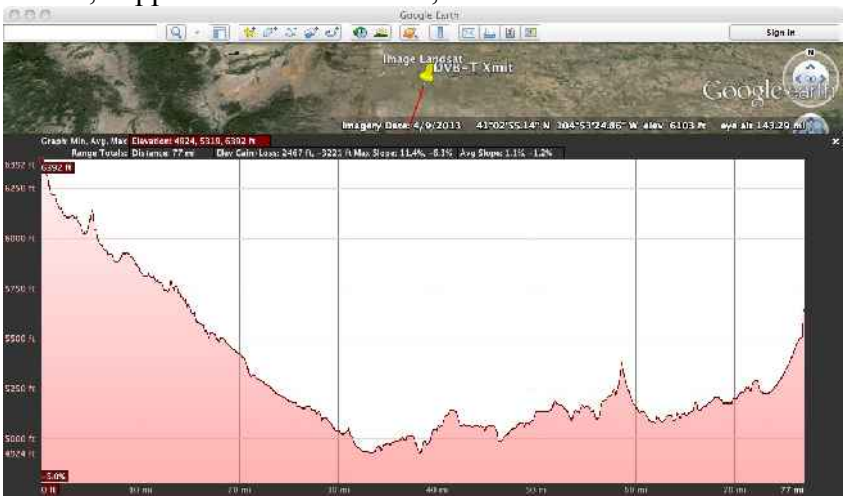

Fig. 4 RF path profile from Cheyenne, Wyoming to N0YE's QTH in Boulder, Colorado. Note: this does not include corrections for the curvature of the earth.

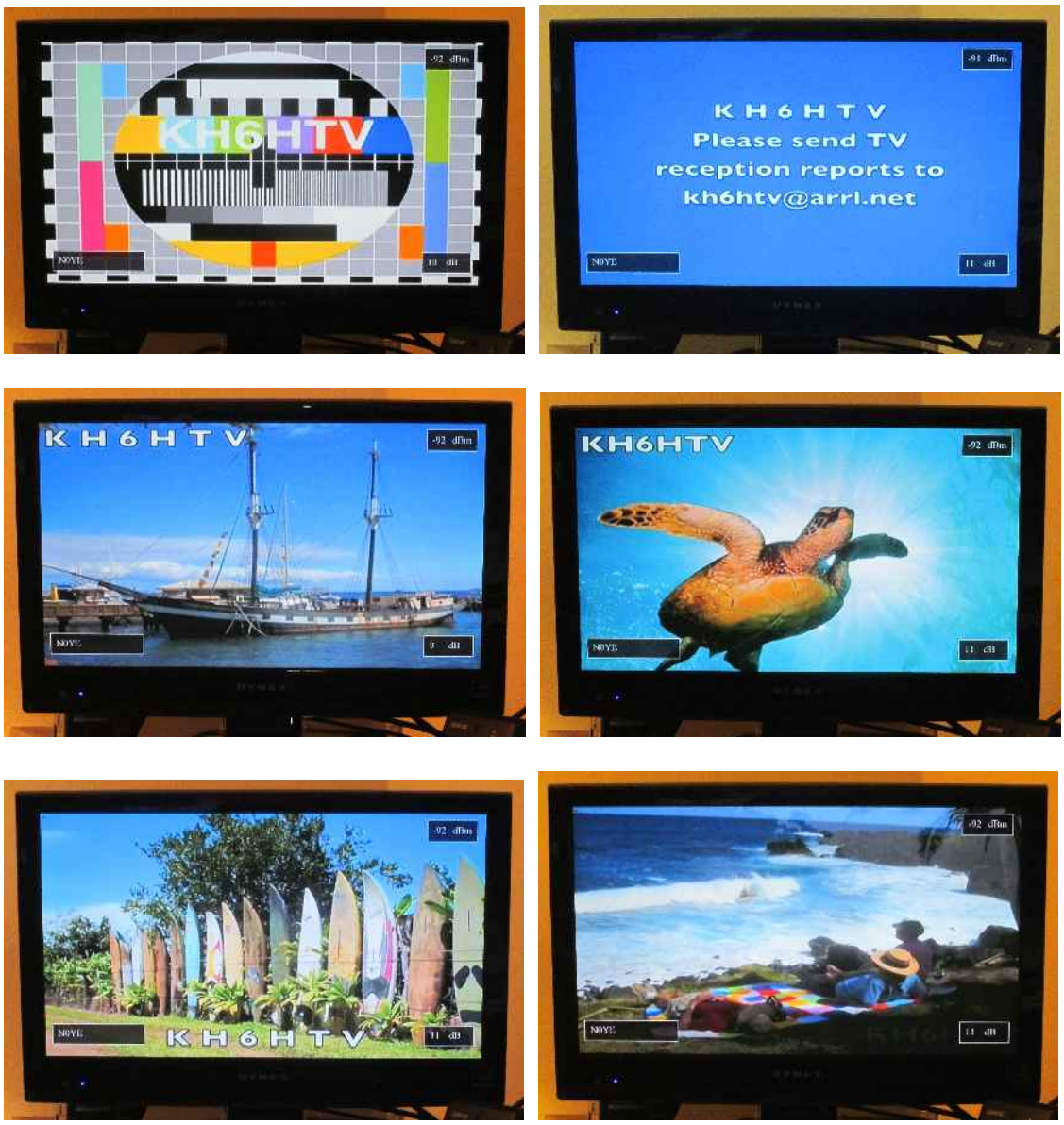

Fig. 5 Various images received by N0YE from KH6HTV. Composite video from pre-recorded DVD slide show. Note: upper right hand corner displayed the received signal strength in dBm (no pre-amp). The lower right hand corner displays the S/N in dB.

Fig. 6 Various Live high-definition, 1080P images received by N0YE in Boulder, CO from KH6HTV in Cheyenne, WY. A Canon hi-def, 1080P, camcorder was used. Images are of KH6HTV in Saab convertible, the "jumble" of electronics gear on the floor of the car, the AT&T microwave tower and Cheyenne TV towers, close up of 70cm, 6 element transmitting yaggi antenna, wide-angle view to south towards Boulder 77 miles away, with I-25 in left side of photo, and telephoto view to the south.

APPENDIX I - DVB-T Transmitter Parameters

Video Source	HDMI (1080P) or Composite (480i)
Aspect Ratio	16:9
Video Compression	H.264 (MPEG-4 - AVC)
Audio Compression	MPEG-2
Frequency	429.000 MHz
Bandwidth	6 MHz
Modulation Mode	QPSK
Output Power	+40 dBm (10 Watts) average
Max. Encoding Rate	6 Mbps
FFT (# of sub-carriers)	8 K
Code Rate (FEC)	7/8
Guard Interval (sync frame)	1/16

For additional description of these parameters, see AN-18, reference [6].