TechTalk109

Looking at the DATV-Express Digital-ATV XMTR Project

by Ken Konechy W6HHC

Most people involved with Amateur TV (ATV), now recognize the advantages of digital-ATV technology over analog-ATV. The digital modulation and Forward-Error-Correction of D-ATV provides superior video quality and robustness against ghosting.

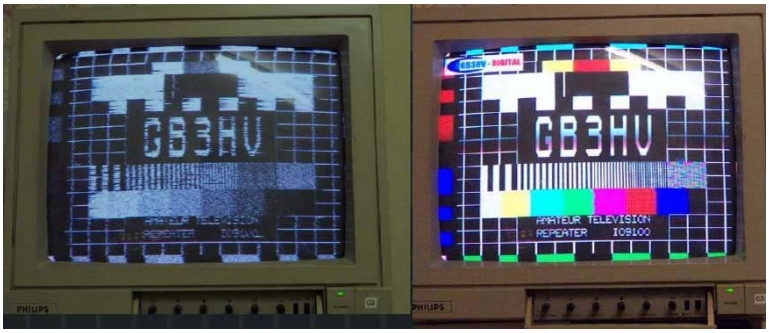

Fig 01 - Comparison of analog-ATV video and D-ATV video using the same antennas with weak sigs (courtesy of G7LWT & GB3HV)

For several years, hams have also recognized that the cost to buy ham-grade MPEG2 encoders boards and Digital-ATV exciter boards is too expensive. A ham-grade set of MPEG-2-and-DVB-S boards from SR-Sys in Germany cost about US$875. The cost of commercial-grade digital-TV boards is even higher. This high cost is known to prevent many hams from "trying Digital-ATV". A group of hams in US and England got together at the end of 2010 to start a project that will lower the cost of DATV considerably.

The open-source project is known as DATV-Express. The team members are:

- Art Towslee WA8RMC – electronics design
- Charles Brain G4GUO – software design
- Tom Gould WB6P – PCB layout design
- Ken Konechy W6HHC – project mgmt & pubs

System Block Diagram for DATV-Express

The most important concept about the DATV-Express board is that it is software-based SDR radio. While the system block diagram for a typical Digital-ATV DVB-S transmitter using the DATV-Express board is shown in **Fig 2**, the modulator chip and software can also produce several other types of modulations and protocols, such as COFDM for DVB-T and 32APSK for DVB-S2. The analog output of a video camera is sent to an MPEG2 encoder unit (made by Hauppauge) to compress the video stream. The video file is stored on a PC and a Windows-based or Linux-based PC does much of the "heavy lifting" to provide real time processing of the Program Stream from the MPEG2 Encoder into a Transport Stream to be used with DVB-S protocol.

The PC processes most of the protocol streams down to the IQ symbol bit-stream that is output via USB2 to the DATV-Express board. Then an FPGA manipulates the data and sends an I-stream and a Q-stream to a modulator. The operating frequency for the DATV transmitter is determined by the PLL within the IQ modulator chip and can be selected by the PC GUI for 70 cm, 23 cm, or 13 cm bands.

The RF output level from the DATV-Express board is fairly low, usually around 0-to10 dBm. So the typical DATV station will probably follow the DATV-Express RF output with about two stages of RF amplifiers to get up to a normal transmitter power level. The

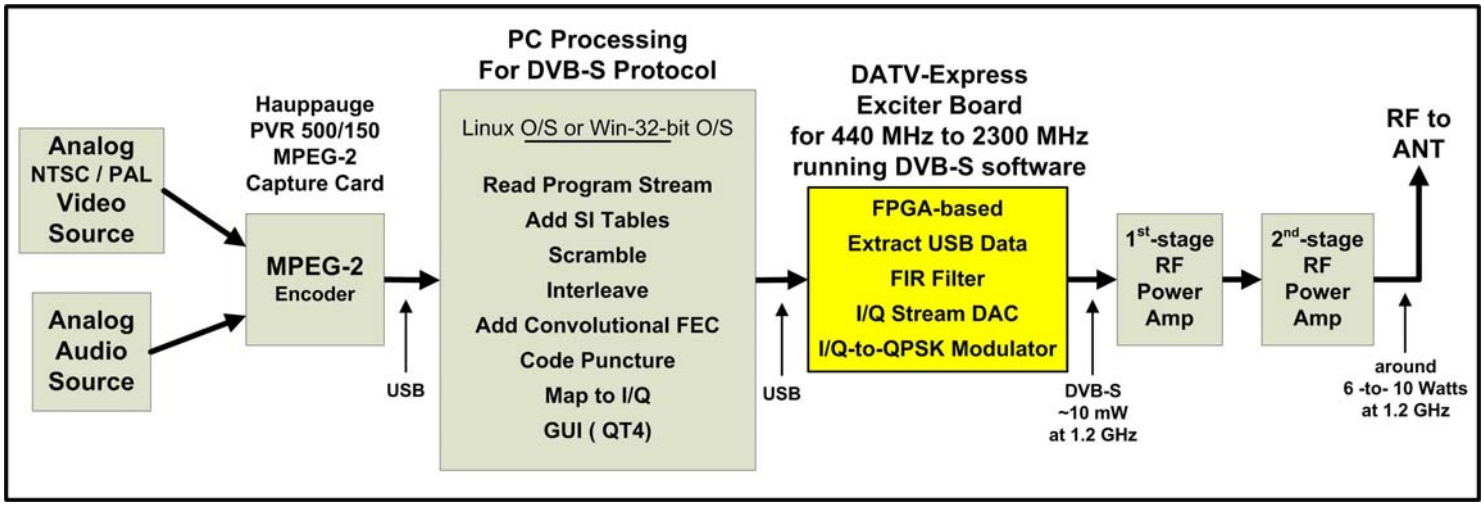

Fig 02 – System Block Diagram of Typical DATV-Express Project DVB-S Digital-ATV Transmitter PC can also run software for DVB-T and DVB-S2 DATV protocols

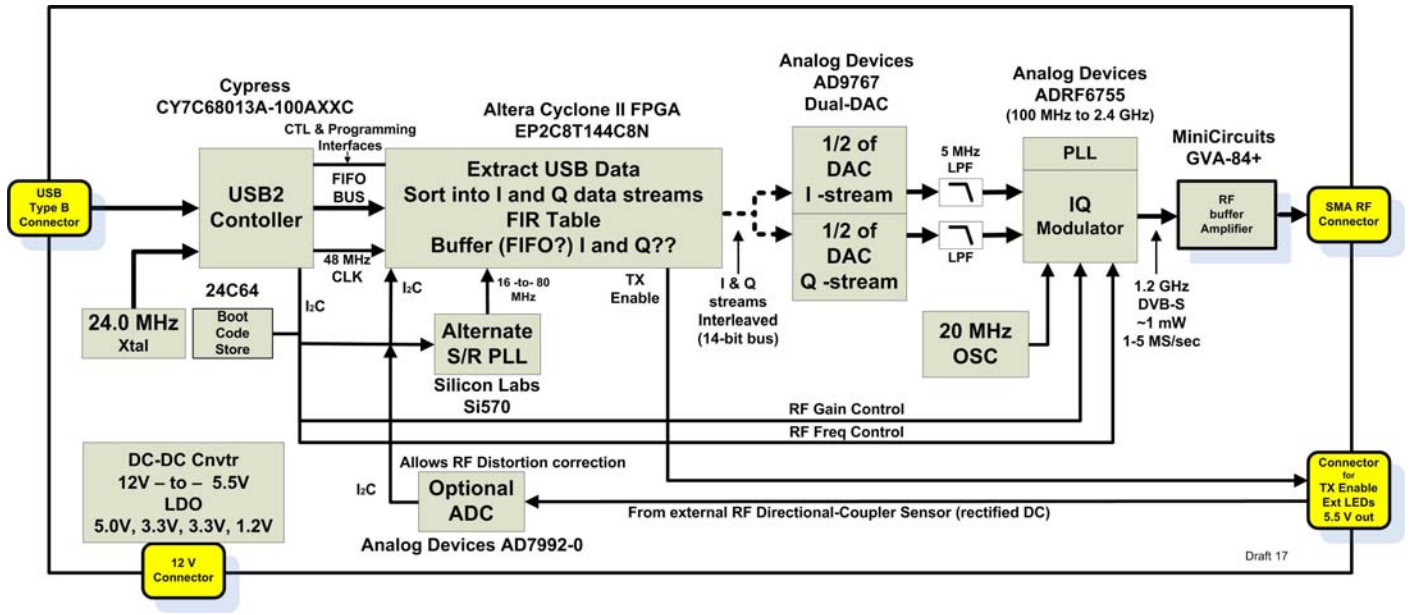

Fig 03 – Block Diagram of DATV-Express Project Digital-ATV Exciter Board

DATV-Express project team also recommends using an external band-pass filter to get rid of harmonics.

The DATV-Express Board

The DATV-Express exciter is a single printed circuit board shown in **Figure 4**. The 4-layer board dimensions are 5.3 x 3.18 inches. The connector for USB2

Fig 04 – the DATV-Express exciter board is a single printed circuit board.

is on the left side. The RF SMA connector is on the right side of the board. **Fig 3** shows a more detailed block diagram for the DATV-Express board design. The PLL on the Analog Devices ADRF6755 IQ modulator allows defining an RF frequency between 72.5 MHz and 2480 MHz. The board contains a total of five DC regulators providing DC outputs between 5.5 VDC to 1.2 VDC for the various chips.

A small MiniCircuits GVA-84+ RF buffer amplifier follows the IQ-modulator chip. Initial bench tests on the first prototype board measured output of 18 dBm on 1.3 GHz. The initial RF etch layout was not done well and resulted in a noisy output and tended to self-oscillate. These RF problems were cleaned up in an etch-update called Version 2. **Figure 5** shows the

Fig 05 - On the left is the clean QPSK modulation Constellation from new second board etch layout. On the right is the noisy QPSK Constellation from the original board etch layout.

cleaned up RF modulation (QPSK constellation) output, compared to the original etch layout. **Figure 6** shows the fairly clean 1.3 GHz RF spectrum. The spurs are down about 55 dB from the CW carrier.

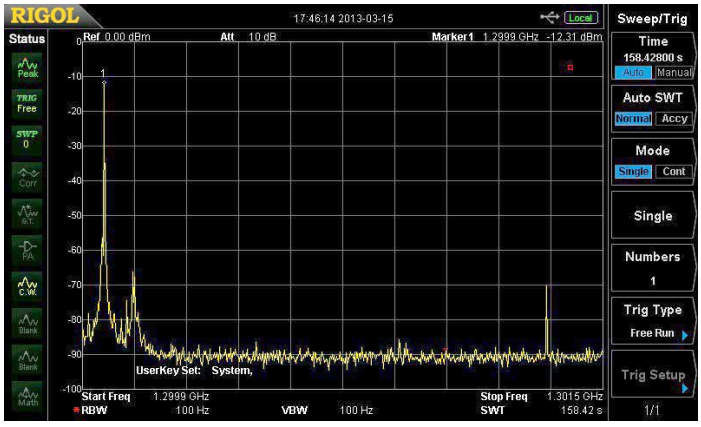

Fig 06 - Spectrum of new board with 1.299 GHz unmodulated carrier signal

Software for DATV-Express

The DATV-Express project uses three sets of software:

- Software that runs on the external PC or Raspberry-Pi, etc.
- Software that runs on the 8051 (inside FX2 USB controller)
- Verilog code that defines the FPGA functions

The main focus of the project currently is getting to release the PC software using 32-bit Linux (Ubuntu

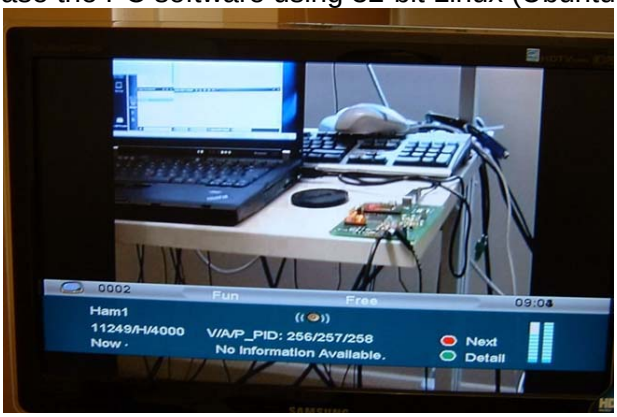

Fig 07 – The first DVB-S video ever transmitted by the DATV-Express board

Ver12.04.02 distribution). Currently the PC software does most of the protocol processing. An important function of the PC is to keep symbol rate constant, no overruns or under runs by adding Null transport packets as needed. The PC software also can download the firmware for the 8051 microcontroller. There is an on-board boot-ROM chip for storing firmware, but the project has not utilized it, yet. Finally, the PC downloads the code that goes into the FPGA.

The USB controller delivers the IQ symbol stream to the FPGA using a 16-bit FIFO on the EP1 bus.

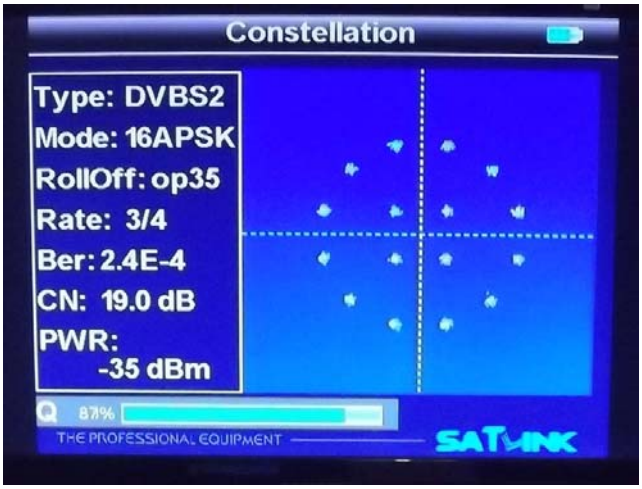

Fig 08 – This constellation of 16APSK digital modulation is being used on a DVB-S2 protocol transmission

The FPGA firmware does a number of shaping functions of the IQ streams as well as calibrating for any IQ modulator offset mismatches in gain.

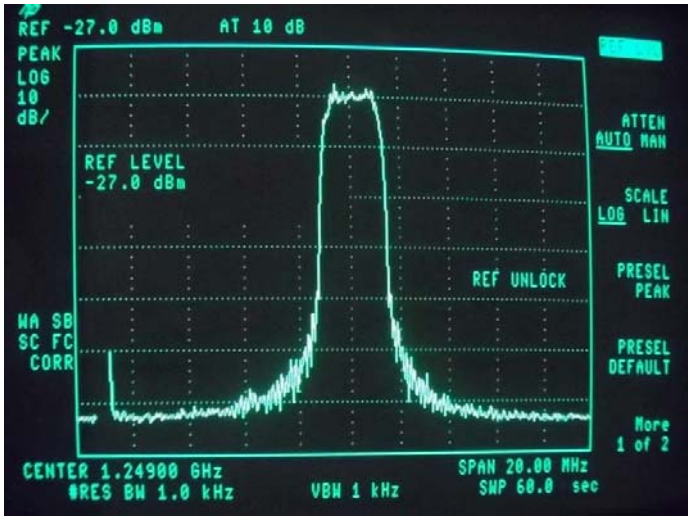

Fig 09 – 2 MSymbols/sec symbol-rate spectrum achieved using DVB-S2 protocol on 1.249 GHz

Figure 9 shows a DVB-S2 signal using 32APSK modulation being filtered by a 95 tap x8 interpolating filter with a rolloff of 0.35 and a compensated root raised cosine response. The filter takes the DVB-S2 symbols and interpolates them by a factor of 8 to put the aliases outside the LC Nyquist filter response. It is difficult to believe that 6 Mbits/s of video is crammed into that piece of spectrum approximately 2.5 MHz wide. The blip on the left hand side at 1.24 GHz is probably a multiple of 20 MHz reference clock signal on the board. The blip remains stationary when the operating frequency changes.

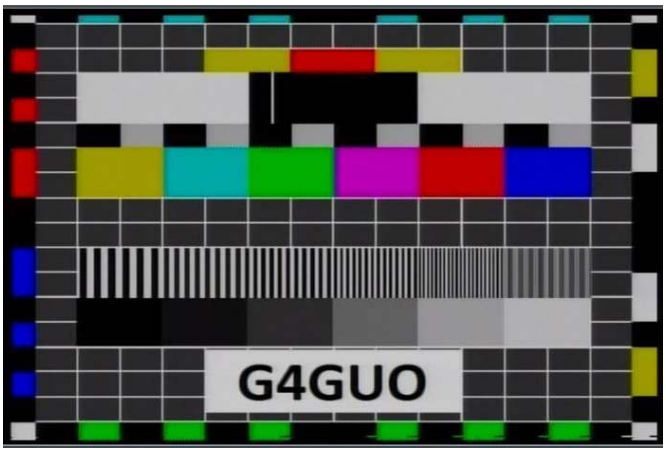

Fig 10 – Test pattern received using DVB-T protocol with 7 MHz bandwidth on 1.3 GHz

The QT4-based GUI on the PC (see **Fig 11**) controls which protocol to download, the PLL frequency, Symbol-Rate, the FEC configuration settings, and the power output level.

Fig 11 – The simple GUI being used by the DATV-Express software

Project Plans

The primary goal right now is to get the board and software ready to distribute into the hands of hams. The team is working towards a "final" etch-update for pre-production to resolve some inner-layers etch clearance issues and make some silk screen changes like adding the CE Mark symbol. The pre-production run will also confirm the correctness of the solder-paste stencil file and the pick-and-place file. The first release of software will run on 32-bit Linux. A little later, further efforts of software will run on 32-bit Windows OS. Right now the team hopes to have a few boards ready towards the end of this year, probably in October.

Another plan is to make all of the design files of this open-source project available to anyone. This includes hardware design (like schematic capture and gerber files) as well as software source code for PC and Verilog. In this way, other hams can experiment and extend SDR and even manufacture the boards if that is their personal goal.

Finally, Charles G4GUO has also been looking at what might be done using the Raspberry-Pi (ARM based) single-board-computer and/or the MK808 media player (also ARM based) to interface with the DATV-Express board as an alternative to using a normal PC. With the help of Rob MØDTS, Charles has played with a modularised version of his DATV host software. It turns out that the Reed-Solomon FEC encoder software consumes a large portion of the ARM resources. Charles has tried porting the Reed-Solomon code to run inside the FPGA. This seems to work well. Also, the project is lucky that Brian G4EWJ has written an optimised version of this module in ARM assembly language. Brian's module uses about 1/4 of the processing cycles that the G4GUO C module does. So we have managed to get the whole thing down from 60% to about 20% of cycles. Further improvements can be made.

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Interesting DATV URLs

- YouTube Video on DATV-Express board – see **http://youtu.be/OXh-anABYaU**
- British ATV Club - Digital Forum – see **www.BATC.org.UK/forum/**
- Yahoo Group for Digital ATV - see **groups.yahoo.com/group/DigitalATV/**
- Orange County ARC newsletter entire series of DATV articles – see **www.W6ZE.org/DATV/**
- DigiLite Project for DATV (derivative of the "Poor Man's DATV" design) see **www.G8AJN.tv/dlindex.html**
- SR-Systems D-ATV components (Boards and complete XMTR) – see **www.SR-systems.de**
- CQ-DATV online (free bi-monthly) e-magazine – see **www.CQ-DATV.mobi**