

Planning a Digital-ATV Station for DVB-S

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Abstract

Most ham radio Amateur Television (ATV) stations and repeaters in use today still utilize analog technology. The purpose of this paper is to explain Digital-ATV (DATV) to other hams, with the hope that it might make the transition from analog-ATV to Digital-ATV a little more straightforward. The paper begins with a review and comparison of various commercial DTV standards that are in use around the world. A top-down design methodology session is then conducted to sort through a number of design alternatives to plan a DATV station. The planning session chooses the DVB-S standard for DATV over the competing United States-based ATSC standard. The paper concludes by describing the Forward-Error-Correction factors and Symbol-Rate factors that determine the RF bandwidth for a DVB-S DATV station.

Key Words

DATV Digital-ATV DVB-S ATSC QPSK 8-VSB FEC Symbol-Rates

1 - Introduction to DATV

For several years, Robbie and I have listened to some interesting ham conversations about “...we hams should change analog ATV over to Digital-ATV (aka DATV) to keep up with technology...”. While the goal seemed simple, the topic was very complex and not easy to grasp. We found that there really was no simple place to go...like a “one-stop-shop” for DATV information, especially here in the United States where ATSC is a standard to be carefully considered. This paper is our attempt to explain Digital-ATV (DATV) to other hams with the hope that it might make the transition from analog-ATV to Digital-ATV a little more straightforward.

1.1 - Why Go Digital ATV?

The main benefits of digital ATV are:

- 1) The picture quality can be nearly perfect most of the time
- 2) Digital techniques allow error correction from noise, multi-path
- 3) Digital techniques allow advanced modulation (less bandwidth) and compression
- 4) Digital TV components for hams will become more common on the marketplace.
- 5) Analog TV components for hams will start to disappear from the marketplace.

1.2 - Different Types of Digital Video Broadcasting Specifications

To start with, there are three fundamental television broadcasting environments that are used for commercial Digital Video broadcasting:

- Cable
- Satellite
- Terrestrial

Each of these three different environments requires a different specification as described below.

1.2.1 - DVB-C (cable)

The DVB-C standard for cable broadcasting was established by the Digital Video Broadcasting organization (www.DVB.org). The environment of cable is very low noise and very low loss. So resistance-to-noise and lots of error-correction-technology is not needed for cable digital TV. The nice cable environment allows implementing higher order modulation schemes starting from QPSK up to 256QAM. Because of the guaranteed low signal path loss in cable, this does not represent a good choice of technology for hams to consider.

1.2.2 - DVB-S (satellite)

The DVB-S standard for satellite broadcasting is designed to work in an environment that contains lots of signal path attenuation and line-of-sight communication. To compensate for the weak signals, the DVB-S standard uses different layers of Forward Error Correction (FEC) for a very robust protection against any kind of errors. One drawback for hams is that DVB-S was NOT designed to deal with multi-path environment situations. Typically, the DVB-S uses MPEG-2 for video data compression and QPSK for modulation and DVB-S can be operated in an RF bandwidth mode as small as 2 MHz. This is the standard chosen by many European and United States DATV groups for digitizing ATV.

1.2.3 - DVB-T (terrestrial)

The DVB-T standard for terrestrial broadcasting by the Digital Video Broadcasting organization is designed to work in the classic situation where a transmitter is broadcasting RF signals to home antennas coupled to a digital TV receiver.

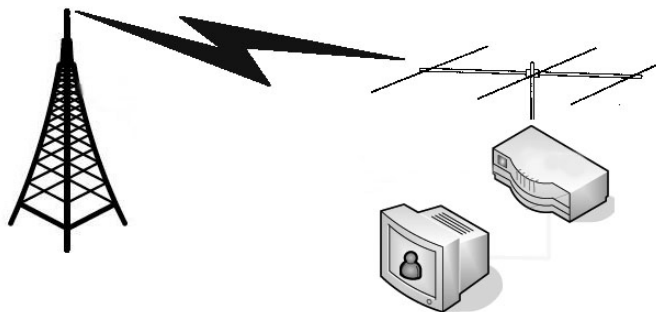


Fig 1 - Terrestrial Reception using a Commercial Set-Top-Box

In over-the-air broadcasts, the DTV technology needs to overcome the destructive effects of multipath reflections. Also, the terrestrial signal path attenuations can be frequency dependent and can result in a partly distorted received signal. The negative effects of multipath reflections can be reduced, by using 16QAM modulation for a low effective bitrate per carrier. To reduce the effective bitrate per carrier, DVB-T spreads out the bitrate over a large amount of carriers. This spreading out will result in 1,705 closely spaced carriers (using COFDM...aka Coded Orthogonal Frequency Division Multiplexing) to create a 6 MHz bandwidth. Creating 1,705 different carrier frequencies with the conventional approach of VCO's and PLL chips is impossible. If we look at the technology choices for DATV, then hams will come to the conclusion that DVB-T is the ultimate approach DATV to use when it comes to robustness. However, the combination of: (1) the high signal-to-noise ratio which is needed for demodulation, and (2) the big impact on hardware implementation, let many hams come to the conclusion that the DVB-T approach is difficult for amateur use.

1.2.4 - ATSC 8-VSB (terrestrial)

What we have not mentioned, so far, is that the Digital Video Broadcasting organization standards are only used for commercial TV in Europe, Asia, and the Pacific...NOT in the United States. In the United States (and Canada), the commercial TV industry uses standards from the Advanced Television Systems Committee (ATSC) a spin-off from the old NTSC TV standards organization. BTW, one exception in the U.S. is that the Dish Network uses DVB-S technology for its home satellite receivers.

8-VSB is the 8-level Vestigial Sideband Modulation method adopted for terrestrial broadcast of the ATSC digital television standard. Like DVB-S, it usually uses MPEG-2 for video compression and multiple layers of Forward Error Correction (FEC) for a very robust protection against any kind of errors. Interestingly, the 8-VSB modulation does not use phase-shift techniques, but uses 8 levels of amplitude for modulation and demodulation. This modulation approach produces a gross bit rate of 32 Mbit/s, and a net bit rate of 19.39 Mbit/s of usable data in a 6 MHz bandwidth. The net bit rate is lower due to the addition of forward error correction (FEC) codes. While, the set-top ATSC DTV boxes are very common in U.S., we believe the current lack of low-cost and fully-compliant ATSC/8-VSB transmitting circuitry, has prevented U.S. hams from more widely using this ATSC 8-VSB approach for ham radio DATV.

1.3 - Drawbacks for DATV

There are two main drawbacks to DATV for ham radio ATV enthusiasts:

(1) Weak Signal Reception

Digital TV technology tends to have "ALL or NOTHING" video performance. The picture is GREAT thru noise and weakening signals...then POOF, it is gone. The transition phase between **ALL or NOTHING** tends to be very narrow. As Henry AA9XW explained in the Amateur Television of Central Ohio News (ATCO), "**Yes, digital [ATV] is 'noise free' until you hit the blue wall. There is 1 dB between perfect and nothing. So don't expect a lot of DX, since you can't find the signal in the noise without a spectrum analyzer and BPF [band pass filter].**"

(2) High Cost of Equipment

One advantage of analog ATV was the cost of equipment, especially transmitting equipment was relatively cheap. You could buy commercial analog CCTV equipment and easily modify it for ham radio ATV use. The receiving circuits can be obtained from old home satellite dishes (DVB-S) that are surplus on e-Bay or internet and can be converted to DATV. But, obtaining transmitters...with image processing and the modulators...is the main problem. There is no cheap surplus satellite transmitting equipment around. Therefore, either you buy boards from European DATV board companies or you buy the Integrated Circuits used by the transmitters and build your own equipment. In our opinion, this last approach takes a lot of engineering/software technical skill that most hams do not possess and requires an investment of a lot of time. SR-Systems in Germany offers a wide selection of printed circuit boards for DATV. Robbie KB6CJZ of OCARC estimates it costs about \$1,200 or more to buy a DATV transmitter exciter, digital band-pass filter, and very-linear power amp. A camera and a wide-bandwidth antenna would also be needed. DATV repeaters are even more expensive.

1.4 - Status of DATV Today

Groups and clubs of DATV enthusiasts have shown that digital technology is possible for hams and that DATV works as expected. **Fig 2** is a block diagram of a basic DVB-S transmitter used by several European groups for DATV.

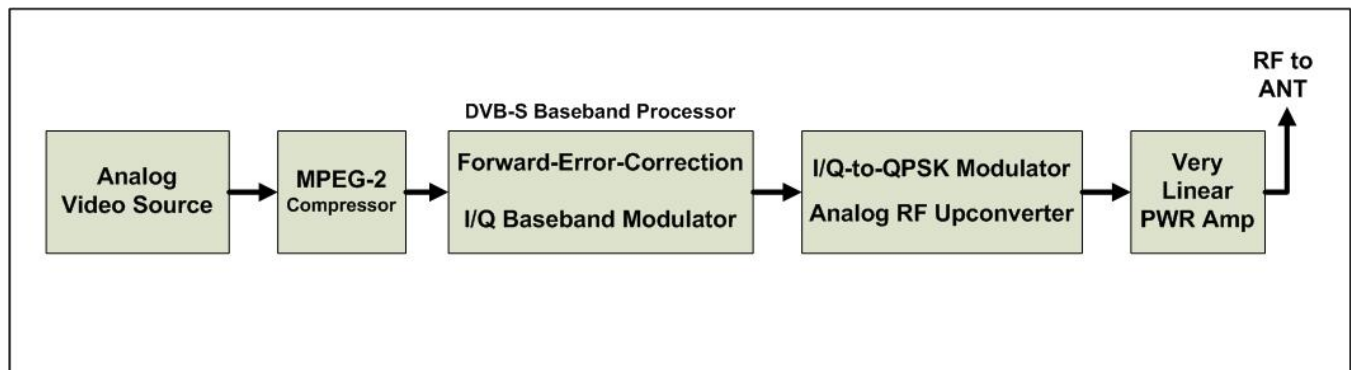


Figure 2 – Block Diagram of Typical DVB-S Transmitter for Digital-ATV

Figures 3 and 4 are European examples of what a ham station looks like and the performance that can be achieved.

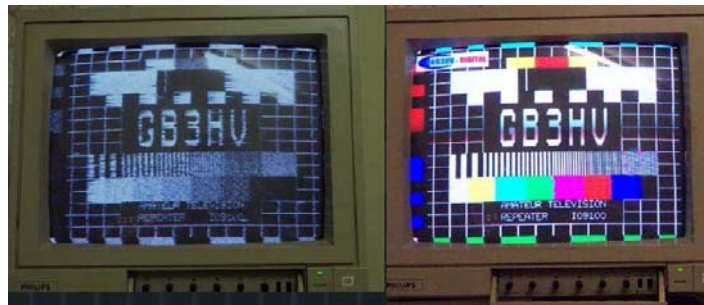


Fig 3 – Comparison of analog Picture and an DATV Picture using the same antennas with weak sigs (courtesy of G8GTZ, G7LWT & GB3HV)

Fig 4 is a picture of an early European DVB-S prototype transmitter demonstrated in 2001 at the Friedrichshafen Ham Fair in Germany by Thomas Sailer-HB9JNX/AE4WA, Stefan Reimann-DG8FAC, et al.

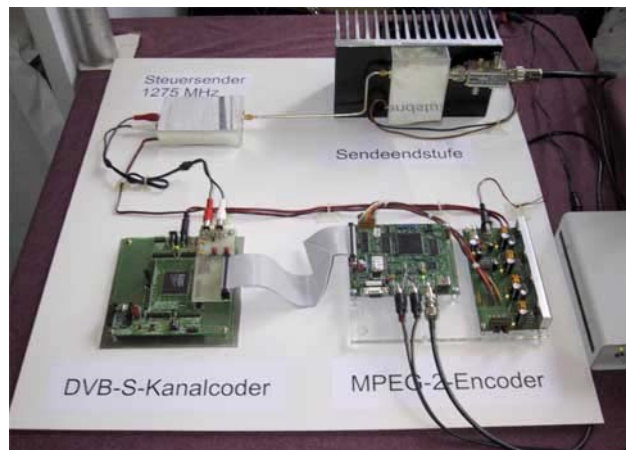


Figure 4 – Prototype DVB-S DATV transmitter similar to the Block Diagram shown in Fig 2 (courtesy of Thomas Sailer-HB9JNX/AE4WA, et al.)

In our probing the internet and through having local conversations, we found that there was a very large burst of DATV efforts by hams (mainly in European) that lasted from about 2000 to about 2004. Many of these early ham radio WEB sites on DATV seemed to eventually go dormant:

- www.D-ATV.com in Holland went dormant in 2005
- pagesperso-orange.fr/jf.fourcadier/television/exciter/exciter_e.htm from Jean-François F4DAY went inactive in 2004/2005
- www.kolumbus.fi/michael.fletcher/dvb.htm Michael Fletcher OH2AUE & OH2FM appears dormant on DATV since 2003
- www.G7LWT.com in UK appears to be now dormant on DATV

From what we have learned, there are only four or five areas in the U.S. that have a DATV repeater or are even testing DATV.

- ATCO has the WR8ATV/R digital DVB-S repeater output on 1260 MHz
- Nick Sayer, N6QQQ from Santa Clara is designing/building/testing an 8-VSB DATV transmitter on 900 MHz
- The Lodi Amateur Radio Club, N6SJV in California has been running a fairly current internet blog about their progress with DVB-S technology.
- There is a ham from Orange County who moved to Idaho who has been actively designing and building and using DATV for several years.
- There are rumors of a group of hams in either Oregon or Washington who are active in DATV (but we can not find them via the internet).

1.5 - What is the Future for DATV??

Based on what we have learned while preparing this paper on DATV, we are surprised by the small amount of current DATV activities in the United States. We expected a lot more activity. There is a great picture-quality-performance attraction for Digital ATV. But, it seems to me that the weak signal picture loss associated with DATV may be taking some of the adventure of DX out of the equation. If we examine the needs of emergency communications groups (like RACES and ARES) to provide ATV pictures back to an Emergency Operation Center (EOC)...currently it is difficult to get a portable analog ATV (point-to-point) through the hills of Orange County California. We can imagine that DATV may have more path loss difficulties and may deliver NO picture at all. Some DATV testing in Orange County needs to be done.

Finally, Ken W6HHC personally finds DATV technology quite complex. Since transmitters for DATV are expensive or you can design your own...I find the complexity of designing my own DATV much much more complex than designing my own SSB transmitter or FM transmitter. In addition, commercial standards continue to evolve. For example: The DVB-S spec is being replaced by the newer "second generation" DVB-S2 standard. While DVB-S2 is faster and better (and even more complex - using a new FEC scheme like Bose-Chaudhuri-Hocquengham), it may threaten to obsolete DATV equipment built with earlier DVB-S designs?

In bringing this introduction to DATV to a conclusion, it appears that the mainline ATV-ers in the United States are currently passing up the "**the Digital Fork in the Road**" that leads towards DATV and continuing to use analog ATV. We will be surprised to see a big increase in DATV usage over the next five years. Only more inexpensive DATV transmitters/components and the recent advent of cheap availability of U.S. DTV antenna set-top boxes can probably change my outlook.

2 - Planning a Digital-ATV Station

This section will cover planning to create our own DATV station. But to a certain extent (especially in the U.S.), Digital-ATV seems like a maze. There are plenty of decisions that need to be made in order to plan for a DATV station:

- Some decisions could be very expensive
- Some decisions may lead to an obsolete design
- Some decisions could have major technical issues

2.1 - What Band Should We Plan for DATV?

Robbie KB6CJZ explains that the view of ham radio bands for ATV and DATV in Southern California looks like this:

- **440 MHz** – very crowded - looks like a difficult band for DATV,
But, RF amps are cheaper
Commercial satellite receivers with up-converters work fine.
- **920 MHz** – presents a tight fit for DATV,
Also, lots of noise from “ISM Part 15” devices.
- **1,200 MHz** – more room for simplex DATV,
Probably no room for a DATV repeater-pair.
RF amplifiers get more expensive.
This is a clear ham band.
FreeToAir receivers are plentiful and the IF is in this band with no LNB needed or conversion.
- **2,400 MHz** – probably has room for a DATV repeater
But, RF amplifiers get even more expensive,
Also, 2.4 GHz region is shared with lots of others commercial services. Most commercial services are just out of edge of the Ham band and some “ISM Part 15” devices share the frequencies with the hams.
- **3,400 MHz** – RF amplifiers get still more expensive.
But, probably has room for a DATV repeater-pair.
Standard satellite FreeToAir receivers are plentiful. LNB’s need no converting.
3.4 GHz is shared only with U.S. Air Force
- **5,800 MHz** – RF amplifiers are expensive.
5.8 GHz region is shared with lots of commercial services and “ISM Part 15” devices
A narrow band, may not have room for DATV repeater-pair.

We made the decision to plan to locate ham home/portable transmitters on the 1.2 GHz band as a good compromise. Later, if we can put up a DATV repeater...the repeater will output on 2.4 GHz or maybe on 3.4 GHz.

2.2 – Use ATSC or DVB-S Modulation Scheme??

The Introduction section explained that Europe/Asia/Pacific were using the DVB-S standard for commercial DTV, using QPSK modulation for video and MPEG-2 compression for audio. But, in the U.S. (and Canada), the terrestrial commercial HDTV standard is called ATSC and uses a modulation scheme called 8-level-VSB for video and AC3 (Dolby) compression for audio. Because of band-plan limitations in U.S., we have selected 1.2 GHz band for doing the planning for DATV. What DATV modulation standard should we choose for our ham station? Let’s look at possible DVB-S and ATSC Transmitters that we can consider.

2.2.1 – First let us Look at DVB-S Transmitters

So far, we have seen that while there are several ham designs in Europe for DVB-S D-ATV boards, especially AGAF and SR-Systems, both in Germany...the lion’s share of units appear

to be produced by Stefan-DG8FAC of SR-Systems (see the link/URL at the end). The block diagram in **Fig 5** uses a SR-Systems MiniMod-DVB-S board and a MPEG-2 board as the heart of a DATV transmitter.

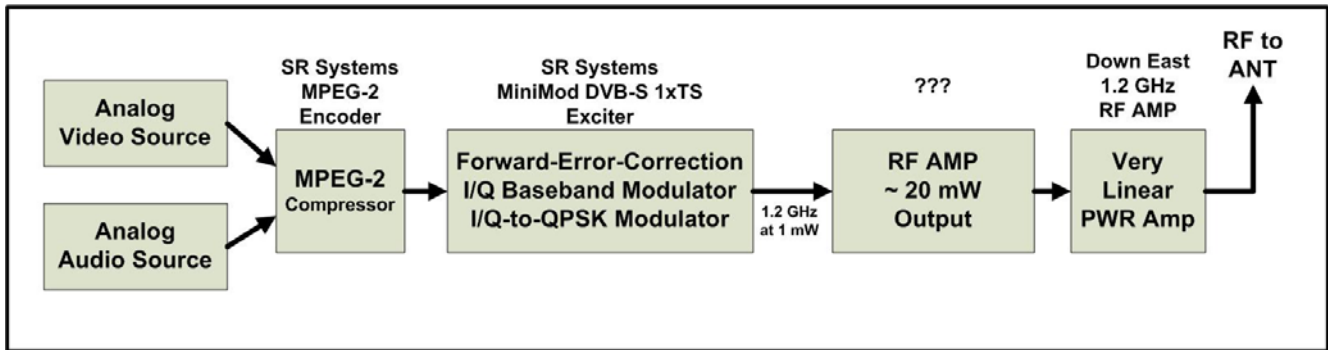


Figure 5 - Block Diagram of DVB-S Transmitter for DATV

The MiniMod board will produce about 1 mWatt RF output. I will need a small RF amplifier to get that power up to about 25 mWatts to drive the 10 Watt RF. All Digital RF modulations require very linear Class A power amplifiers. We plan to run a 30W 1.2 GHz linear amp at about 10 watts or so. Note that the SR-Systems datasheets caution that the RF output of the MiniMod board is UNFILTERED. Stefan-DG8FAC has explained to us that this note means that we need to suppress the second harmonic and the third-harmonic a little. Following the MiniMod output with two 1.2 GHz amps provides the required harmonic suppression. The DVB-S 1xTS DATV RF signal bandwidth will be about 2 MHz -to- 3 MHz wide (depending on Symbol-Rate settings discussed later in Section 3). **Table 1** below looks at an estimate of costs for a DVB-S transmitting station.

Table 1 – Cost Estimate of DVB-S Transmitter

Item	Description	Manufacturer	Model	Cost Estimate Low end	Cost Estimate High end
1	MPEG Encoder Board	SR-Systems	MPEG Encoder	\$290	\$360
2	1.2 GHz FEC & IQ Modulator for DVB-S	SR-Systems	DVB-S 1xTS MiniMOD	\$470	\$540
3	First RF amp	??	(about 50 mW)	\$25	\$50
4	RF Power Amplifier 30W (very linear)	Down East Microwave	Part Number 2330PA	\$240	\$240
	TOTAL			\$1,025	\$1,190

2.2.2 – Next let us Look at ATSC Transmitters

While there are several ham designs in Europe for DVB-S DATV boards...there is only one ham design that we can find for an ATSC DATV transmitter that provides us with lots of internet material for easy research. Again, Stefan-DG8FAC of SR-Systems in Germany

produces a board for the U.S. 8VSB terrestrial video standard. Block diagram in Fig 2 uses the SR-Systems MiniMod-ATSC board and MPEG-2 board as the heart of a DATV transmitter. There is one “quirk” with MiniMod-ATSC design. The U.S. ATSC standard calls for transmitting compressed audio in AC3 format (Dolby), but the Dolby licensing fees for AC3 are very expensive. SR-Systems elected to pair up the 8-VSB video with MPEG-2 audio to avoid the AC3 licensing fees. This 8-VSB/MPEG-2 combo works in many receivers in United States, as we will see later in Section 2.3 this paper, but is not compatible with the plentiful and really cheap ATSC terrestrial SetTopBoxes.

The ATSC transmitter block diagram shown in **Fig 6** looks almost the same as the DVB-S block diagram that was shown back in **Fig 5**.

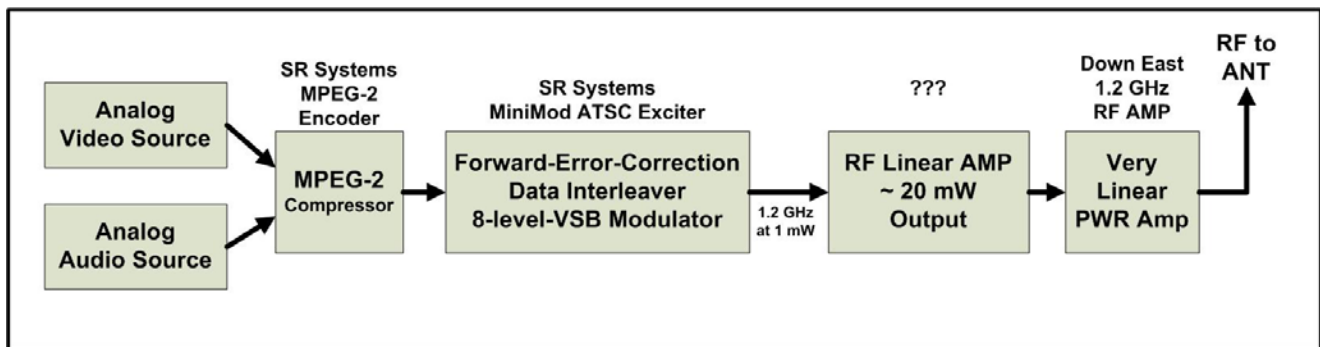


Figure 6 - Block Diagram of ATSC Transmitter for DATV

The MiniMod ATSC board will also produce about 1 mWatt of RF output. I will need a small RF amplifier to get that power up to about 25 mWatts to drive the final 10 Watt RF amplifier. All Digital RF modulations require very linear Class A power amplifiers. We plan to run a 30W 1.2 GHz amp at about 10 watts or so. Note again that the SR-Systems datasheets caution that the RF output of the MiniMod board is UNFILTERED. What this means is that we need to suppress the second harmonic and the third-harmonic a little. Following the MiniMod output with two 1.2 GHz amps provides the required harmonic suppression. The 8VSB signal will be about 5.5 MHz wide. **Table 2** looks at an estimate of costs for an ATSC transmitting station.

Table 2 – Cost Estimate of ATSC Transmitter

Item	Description	Manufacturer	Model	Cost Estimate Low end	Cost Estimate High end
1	MPEG Encoder Board	SR-Systems	MPEG Encoder	\$290	\$360
2	1.2 GHz FEC & IQ Modulator for ATSC	SR-Systems	ATSC MiniMOD	\$852	\$925
3	First RF amp	??	(about 50 mW)	\$25	\$50
4	RF Power Amplifier 30W (very linear)	Down East Microwave	Part Number 2330PA	\$240	\$240
	TOTAL			\$1,407	\$1,675

2.3 – Comparing Possible DATV Receiving Stations

Now we will look at possible choices for the DATV receiving station. The video can be displayed on an old analog TV, a new DTV, or a desk-top computer or a notebook computer. In **Fig 7**, we show nine possible alternative configurations for DATV receivers: four configurations are aimed at receiving ATSC ham signals and five configurations are aimed at receiving DVB-S ham signals.

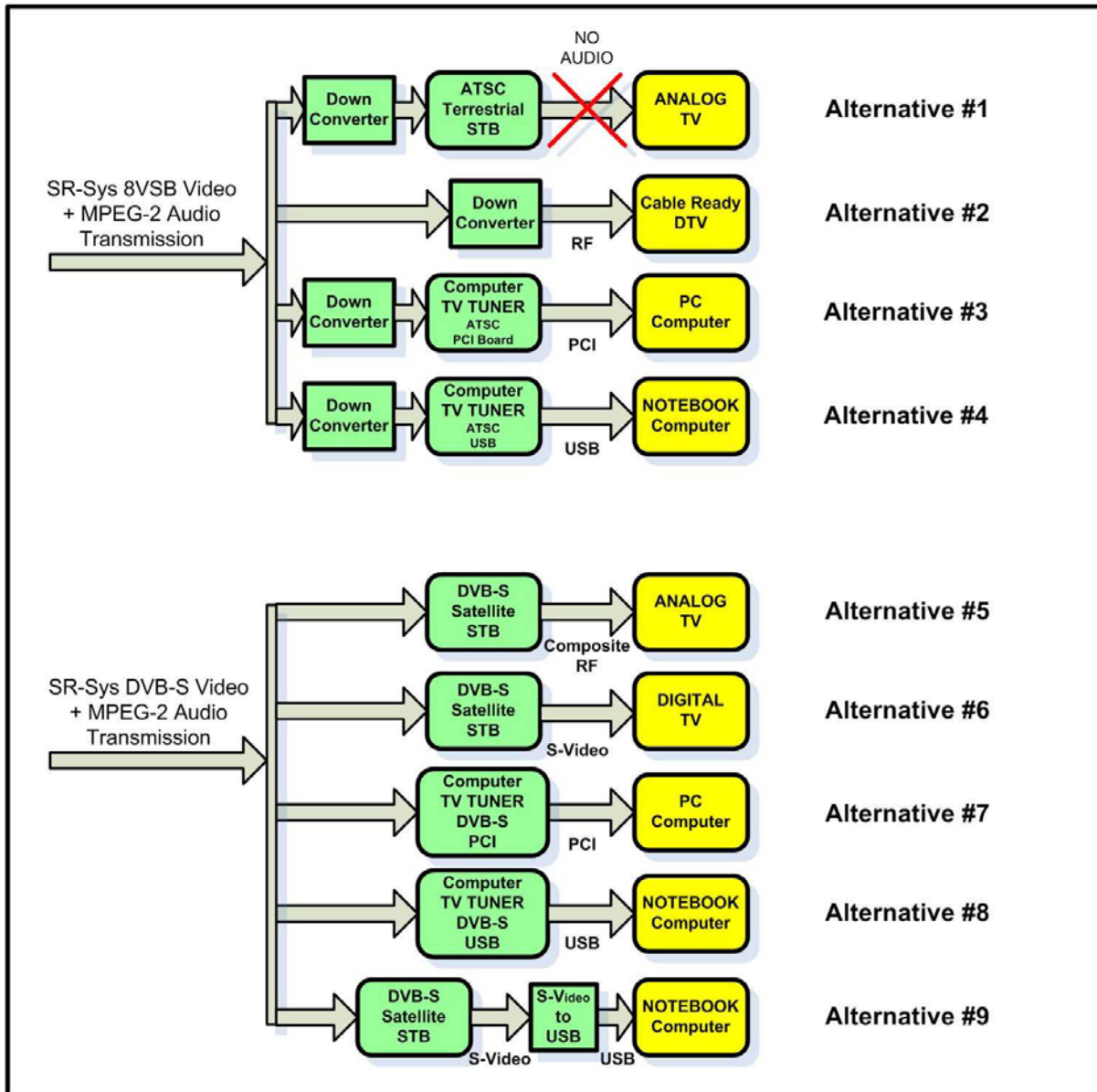


Figure 7 - Possible DATV Receiver Choices

Now we will walk through each of the receiving station alternatives that are shown in **Fig 7** ...starting with receiving ATSC ham signals.

Alternative 1 – Using a Terrestrial ATSC STB

The first approach for receiving ATSC is to use the cheap (\$50 new) ATSC terrestrial SetTopBoxes that have been made common by the U.S. government preparations for eliminating commercial analog TV broadcasts. The MPEG-2 audio compression from the **Fig 6** ATSC transmitter appears to create a real problem for this approach. The STB is expecting the AC3 format (not MPEG-2) for the incoming compressed audio. We have found no U.S. hams who have succeeded in receiving the intended audio ATSC DATV transmission from the SR-Systems MiniMod on these ATSC terrestrial SetTopBoxes.

Alternative 2 – Using Cable-Ready DTV

In the second approach, some models of “cable-ready” digital TVs can receive QAM (for cable) as well as ATSC (for terrestrial) and will correctly handle the MPEG-2 audio OK. Nick-N6QQQ in Santa Clara has reported he has tested this approach with the MiniMod ATSC board and it does work well. This approach needs a front-end down-converter to take the received 1.2 GHz signal and bring it down to perhaps the 480-to-700 MHz range of U.S. ATSC DTV tuners. Perhaps some cable-ready DTVs may not work?

Alternative 3 – Using a Computer PCI ATSC Tuner

In the next approach, we use a PCI board designed to add an ATSC TV tuner to a PC computer. Nick-N6QQQ has reported MiniMod ATSC success with using computer peripheral tuners, simply because all they do is take the 8VSB and put out the MPEG-2 transport stream. The computer winds up doing the rest of the work by decoding the MPEG-2 video and the MPEG-2 audio. The Hauppauge WinTV-HVR-1600 PCI TV Tuner Card – 1101 covers analog (NTSC) and DTV (ATSC) for under \$100. Another interesting approach for a PC computer is the Silicon Dust HD HomeRun box that networks to the computer. Again, we need a down-converter to take the incoming 1.2 GHz signal and bring it down to the range of U.S. ATSC DTV tuners.

Alternative 4 – USB ATSC Tuner for Notebook

In this approach, we use an ATSC tuner with a USB output that can deliver to a Notebook computer (no room for PCI card). The notebook will again accept the MPEG-2 transport stream output and provide for the presenting the video and audio. The Hauppauge WinTV-HVR-950Q TV Tuner Stick can be purchased on the internet for around \$70 new. Again, we need a down-converter to take the incoming 1.2 GHz signal and bring it down to the range of U.S. ATSC DTV tuners.

Alternative 5 – Using a Satellite DVB-S STB

Our first approach to receiving DVB-S transmissions uses a DVB-S satellite box (commonly called Free-To-Air or FTA). A “composite RF” output from the STB can go straight into an old analog TV set. The frequency range of the DVB-S STB tuner range for satellites will include

the 1.2 GHz ham band, so no down-converter is needed. The ViewSat VS2000 Xtreme is an example of a DVB-S FTA STB that can be purchased new for about \$100 or even less for a used unit on e-Bay.

Alternative 6 – Using DVB-S STB with DTV

This approach is the same as the DVB-S alternative #5 above, except it takes the S-Video output of the Free-to-Air DVB-S SetTopBox to provide the input to a HDV set.

Alternative 7 – Computer PCI DVB-S Tuner

In this approach, a PCI DVB-S tuner board is installed in the PC computer. The Hauppauge WinTV Nova-s PLUS DVB-S PCI Card costs less than \$100.

Alternative 8 – USB DVB-S Tuner for Notebook

This approach uses a DVB-S USB tuner box (for example: the SkyStar USB2 model costs about \$100) to output directly to the USB port on the notebook computer.

Alternative 9 – Using DVB-S STB with Notebook

This approach is very similar to #6 above except we add an S-Video to USB converter to take the STB output to the USB input on the notebook computer. A typical S-Video-to-USB converter is the Startech.com USB 2.0 and costs about \$50 through Radio Shack (in addition to the STB cost) and other stores on the internet.

2.4 - Selecting Our DATV Station

Robbie and I had both hoped for an ATSC approach for DATV because of the easy availability of low-cost terrestrial STBs in the U.S.. But, neither of us wanted to deal on a trial-and-error basis to see if equipment we purchased for receivers would really work with the current “MPEG-2 audio quirk” of ATSC DATV transmissions. So our decision is to plan for a DVB-S DATV station here in Southern California. Also, by comparing the cost estimates in **Table 1** and **Table 2**, you can see we will save almost \$400 by choosing a DVB-S transmitting station instead of an ATSC station. As a note...if it was possible, both of us would gladly pay an extra US\$50 or 50EUR for an AC3 Dolby license charge to avoid the “MPEG-2 audio quirk” situation that would allow us to go to the ATSC route with full compliance.

Now that we have chosen our DATV transmitting station, any of the DATV receiving station approaches ALTERNATIVE #5 through ALTERNATIVE #9 in **Fig 7** will work well. The costs of each of these five receiving approaches are reasonable. So the reader can choose the approach that appeals to him. Ken-W6HHC will choose ALTERNATIVE #8 because he wants to use his notebook computer (instead of a TV set) for his home DATV station. Robbie-KB6CZJ prefers to go with ALTERNATIVE #5, because he prefers the wide-availability and the feature-rich-capability of a DVB-S FTA SetTopBox.

There are still a few details to sort out for our station, but hopefully you can see that this top-down approach to planning a DATV station provides a “big picture” of alternatives...allows us to understand the trade-offs....and allows a direction to be chosen.

3 - Understanding Symbol-Rates, FEC and RF Bandwidth for DVB-S

Ken W6HHC does not feel comfortable unless he understand the basic concepts he is working with. The promise of DATV to deliver video in “less bandwidth than analog ATV” is a great goal, but lets study the factors affecting RF bandwidth for DVB-S so that the factors are fully understood.

Using the DVB-S standard to transmit a digital ATV signal involves:

- QPSK (Quadrature Phase Shift Keying) modulation
- FEC (Forward Error Correction) algorithms
- MPEG-2 compression data rates for video
- Video bit-rate needed
- Net Data Bit-Rate available
- Symbol-Rates
- RF Bandwidth

This section will now walk through these various DATV factors and arrive at determining the resulting RF bandwidth.

3.1 - Video Data-Rate and Compression

Fig 8 shows the basic flow of video stream and data rates through a DVB-S transmitting block diagram. For DATV, the analog camera output is first digitized by the MPEG-2 Encoder board that is shown in **Fig 8**, and then the video stream is compressed by the MPEG-2 algorithm.

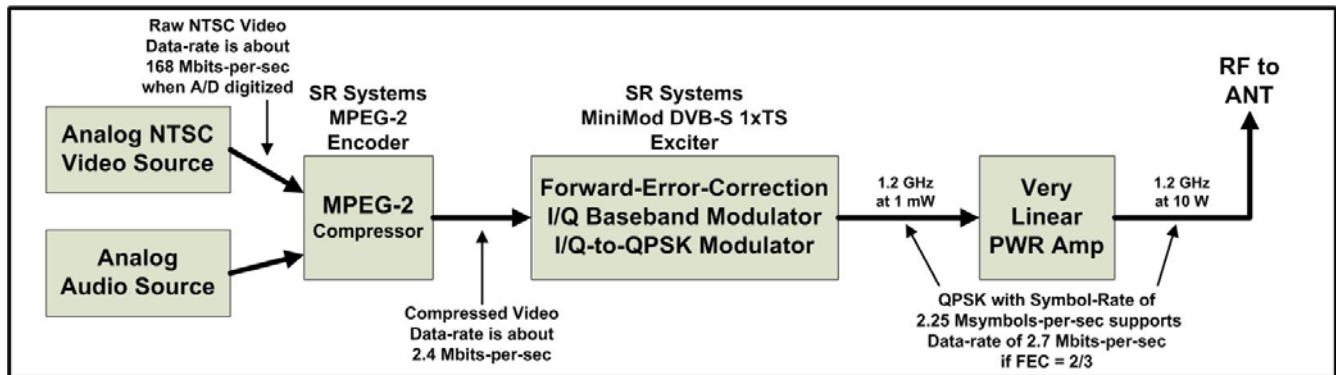


Figure 8 – DATV Block Diagram Showing Various Data-Rates and Symbol-Rates for DVB-S QPSK (for 2.25 Msymbols-per-sec, the Bandwidth is 3 MHz)

The information in **Table 3** comes mainly from the excellent paper written by Dr Gorry Fairhurst in 2000, called "MPEG-2 Overview". [Note: you can find a link to this paper in Wikipedia.] This table allows you to compare the video data stream rates with and without MPEG-2 compression. The reason the compressed video data rate varies in **Table 3** is that the amount of motion in the picture affects the value. The low compressed value means little motion in the video scene and the higher value means a lot of motion.

Table 3 – Camera Video Data Streams and MPEG-2 Data Streams

Video Data Stream	Data-Rate	Notes
Analog NTSC camera	168 Mbits/sec	A/D digitized, uncompressed
NTSC MPEG-2	2-3 Mbits/sec	compressed
VHS MPEG-2	1-2 Mbits/sec	compressed
Analog PAL camera	216 Mbits/sec	A/D digitized, uncompressed
PAL MPEG-2	2.5-6 Mbits/sec	compressed
HDTV camera	1-1.5 Gbits/sec	uncompressed
HDTV MPEG-2	12-20 Mbits/sec	compressed

Notice in **Table 3** that the uncompressed NTSC camera video stream is 168 Mbits/sec, while the uncompressed PAL camera video stream is 216 Mbits/sec. The NTSC video stream data-rate is a 22% reduction from PAL data-rate.

Stefan-DG8FAC of SR-Systems (located in Germany...see links at the end) has explained to me that in Europe many hams set the MPEG-2 output data-rate to be 2.5 Mbits/sec for PAL. Stephan further suggests that the MPEG-2 output data-rate for NTSC would be about the same as PAL. Ken-W6HHC still suspects that there should be about a 22% reduction in MPEG-2 output data-rate from PAL, to about 2.0 Mbits/sec. We will plan for about a 2.5 Mbits/sec video stream. But, when we finally put together a first station DVB-S transmitter, we will measure the NTSC MPEG-2 output to see if the data-rate can be reduced to 2.0 Mbits/sec.

3.2 - FEC Inflation of Video Stream Data-Rate

Forward Error Correction (FEC) is a technology that not only can detect an error on the received signal, but adds enough redundancy of the data so that it can correct the wrong bit. It can correct two wrong bits. Since redundancy increases the data-rate of the video stream, there is a trade-off between more redundancy and the required video data-rate becoming too large. As we will see a little later in this article, the larger the video stream data-rate, the higher the required RF bandwidth. So at some point the FEC algorithm will not have enough redundancy to correct too many errors. Then, if not all the errors are corrected the DATV screen will eventually go blank.

The DVB-S commercial television standard uses two different Forward-Error-Correction (FEC) algorithms together in order to provide protection against noise errors and multi-path errors. The first FEC algorithm is called Viterbi. The second FEC algorithm is called Reed-Solomon.

The Viterbi FEC algorithm can be configured for different levels of error correction. These different Viterbi configuration/redundancy settings are usually called: 1/2, 2/3, 3/4, 5/6 and 7/8. The first number (“1” in the case of configuration “1/2”) is the number of input bits into the algorithm. The second number (“2” in the case of configuration “1/2”) is the number of output bits from the FEC_{viterbi} algorithm. So the MPEG-2 output data stream is “inflated” 100% by this FEC algorithm configured for 1/2. That is...for every bit going into the FEC engine, two bits come out. A FEC_{viterbi} algorithm configured for 3/4, for example, would inflate the MPEG-2 output data stream by 33%. So FEC levels can really inflate the data-bit-rate going to the RF modulator; the MPEG-2 algorithm compresses the video stream, but the FEC algorithms start to expand the required data-bit-rates again.

The Reed-Solomon FEC algorithm has a fixed configuration setting. Its data stream “inflation rate” is 188/204. So for every 188 bits going into the FEC_{reed-solomon} algorithm, 204 bits will come out...an additional FEC inflation of 8.5%.

3.3 - Digital Modulation Symbols and Symbol-Rates

Digital modulation technology like BPSK (for example PSK-31), QPSK (Quad Phase Shift Keying for example like DVB-S) and QAM256 (Quadrature Amplitude Modulation with 256 “constellation points”) have the ability to put more information into a narrow frequency spectrum than analog modulation. The complexity of the digital modulation scheme, allows us to pack more “data bits” into each SYMBOL. **Table 4** lists out the details on how many data bits can be packed into a symbol for several well know digital modulation technologies.

Table 4 – Symbol Bit-Packing for Various Digital Modulation Technologies

Modulation Scheme	Data Bits per Symbol (Me)
BPSK	1
QPSK	2
8-VSB	3
QAM16	4
QAM256	8

This table means that QPSK will pack two data bits into each symbol being modulated. If we know the final output data-bit-rate (I will call this inflated data rate the “Gross Data-Bit-Rate”) we need for the television signal, then the “symbol-rate” we need is exactly one-half of that data-bit-rate. For example:

$$\begin{aligned} \text{Gross Data-Bit-Rate} &= 4.5 \text{ Mbits/sec} \\ \text{Symbol-Rate Needed} &= 2.25 \text{ Msymbols/sec} \end{aligned}$$

The formula to calculate the Symbol-Rate setting that we need for our DVB-S transmitter is:

$$\text{Symbol-Rate Needed} = \frac{\text{NDBR}}{\text{Me} \times \text{CRv} \times \text{CRrs}}$$

Where:

NDBR = Net Data Bit Rate (aka the information rate)
Same as MPEG-2 output data rate listed in Table 3

Me = Modulation Efficiency (value is 2 for QPSK is listed in Table 4)

CRv = Correction Rate setting for Viterbi algorithm (1/2, 3/4, etc)

CRrs = Correction Rate value for Reed-Solomon algorithm is 188/204

We will now calculate an example for QPSK where the output of MPEG-2 is 2.4 Mbits/sec and $\text{FEC}_{\text{viterbi}}$ is configured to 1/2.

$$\text{Symbol-Rate Needed} = \frac{2.4 \text{ Mbit/sec}}{2 \text{ bit/symbol} \times (1/2) \times (188/204)}$$

$$\text{Symbol-Rate Needed} = \frac{2.4 \text{ Mbit/sec}}{0.921 \text{ bit/symbol}}$$

$$\text{Symbol-Rate Needed} = 2.60 \text{ Msymbol/sec}$$

If we change the $\text{FEC}_{\text{viterbi}}$ setting to 3/4, then the CRv value becomes 3/4 and the results are:

$$\text{Symbol-Rate Needed} = 1.73 \text{ Msymbol/sec}$$

The Symbol-Rate that is needed was reduced because the “inflated data-rate” caused by a lot of FEC redundancy was reduced. If you look at **Table 5**, it shows the Net Data Bit Rate that can be supported by a particular Symbol-Rate using several FEC settings. The FEC setting needs to result in a number of Net Data Bit Rate that is at least 2.4 Mbits/sec. The red values

in the table show FEC settings or Symbol-Rates that result in a Net Data Rate of less than 2.4 Mb/s that we set as our goal for MPEG-2 video stream output.

Table 5 – Net Data Bit-Rates for DVB-S at a given RF Bandwidth

Modulation	FEC Coderate	DVB-S RF BANDWIDTH for DATV (RF BW = SymbolRate x 1.33)					
		2.0 MHz (SR = 1.5 MS/sec)	2.5 MHz (SR = 1.88 MS/sec)	3.0 MHz (SR = 2.25 MS/sec)	4.0 MHz (SR = 3.0 MS/sec)	5.0 MHz (SR = 3.75 MS/sec)	6.0 MHz (SR = 4.50 MS/sec)
QPSK	1/2	1.38	1.73	2.07	2.76	3.46	4.15
	2/3	1.84	2.30	2.76	3.69	4.61	5.53
	3/4	2.07	2.59	3.11	4.15	5.18	6.22
	5/6	2.30	2.88	3.46	4.61	5.76	6.91
	7/8	2.42	3.02	3.63	4.84	6.05	7.26

(NOTE-1: NTSC Analog Camera produces about 2.4 to 2.5 Mb/s of MPEG-2 output for Ham Radio type broadcasts)

(NOTE-2: The Net Data Bit-Rate values inside the Table need to be at 2.4 Mb/s or larger to support the expected camera data rate coming from MPEG-2 encoder)

(NOTE-3: The Net Data Bit-Rate values inside the Table shown in RED (with strikethrough) are Net Data Bit-Rates that will not support the video data stream.)

3.4 - RF Bandwidth for DVB-S DATV

It turns out, one of the advantages of digital-ATV is it can be more bandwidth-efficient than analog ATV. With QPSK modulation you actually have the ability to easily make the DATV RF bandwidth as narrow as 2 MHz or 3 MHz without giving up any noticeable quality. This is because the commercial DTV standards planned to transmit several Television streams inside one normal (old) RF TV bandwidth.

The final formula is for DATV Bandwidth (BW). For QPSK modulation, the formula for RF BW is:

$$\text{RF BW} = 1.33 \times \text{Symbol-Rate}$$

This Bandwidth is the spacing that can be used for placing adjacent DATV station center-frequencies. This value of Bandwidth is where the signal is down about -15 dB or more. The expression "occupied bandwidth" is sometimes used to refer to a bandwidth that is 1.19 times the symbol rate, where the signal is down by approximately -10 dB.

If the Symbol-Rate used is 2.25 Msymbols-per-sec for example, then:

$$\text{RF BW} = 1.33 \times 2.25 \text{ Msymbols/sec} = 3.0 \text{ MHz}$$

If we can use a Symbol-Rate of only 1.5 Msymbols/sec, then the bandwidth reduces to:

$$\text{RF BW} = 1.33 \times 1.5 \text{ Msymbols/sec} = 2.0 \text{ MHz}$$

Again, **Table 5** on the preceding page provides an overview of what RF Bandwidth you can choose and what the resulting Net Data Bit Rate can be supported will be for various FEC selections.

4 – Conclusion and Our Future Plans

In reviewing the results in **Table 5**, we have concluded that we will use an RF Bandwidth of 2.5 MHz to support an NTSC MPEG-2 output of 2.4 Mbits/sec by selecting FEC to be 3/4. We plan to put together a DATV station soon. When we do test the station, we will measure the NTSC MPEG-2 video stream that is really required. If our suspicions that we will see a NTSC MPEG-2 video stream at around 2Mbits/sec are confirmed, then we probably change to a 3 MHz RF BW by using the FEC setting of 1/2. This FEC setting will produce high DATV signal correction capability in one-half of the normal 6 MHz analog ATV bandwidth.

This paper has tried to explain many DATV concepts in order to provide understanding to hams about what is involved, without diving into the intense mathematics that is so common in Digital Communications text books. The internet is a wonderful resource. The internet and Google and Bing make research so much easier and faster than paging through magazines and books. Probably 95% of the material in this paper would never have been known to us in Orange County, California, if it were not for the great DATV projects and papers that were created and documented and shared by so many hams in Europe.

Our plans are to first order a first set of DVB-S boards from SR-Systems and do some testing and some measurements. We have plans to do some field tests to determine the picture quality sent to an Emergency Operations Center (EOC) from portable locations in the hills of Orange County. If these efforts go well, we will spread the word of DATV, try to lure more hams to start using DATV, and then we start planning for a DATV repeater.

Referenced Links and Related Links

Advanced Television Systems Committee (ATSC)
www.ATSC.org

Digital Video Broadcasting organization (DVB)
www.DVB.org

Amateur Television of Central Ohio
www.ATCO.TV

British ATV Club - Digital Forum
www.BATC.org.UK/forum/

CQ-TV magazine from BATC (mostly analog)
www.BATC.org.uk/cq-tv/

Darren Storer-G7LWT on "DATV / Digital Amateur Television Primer"
www.G7LWT.com/datv.html

Thomas Sailer-HB9JNX/AE4WA, et al on "Digital Amateur TeleVision (D-ATV)"
www.baycom.org/~tom/ham/dcc2001/datv.pdf

DXzone Digital-ATV Links
www.dxzone.com/catalog/Operating_Modes/Digital_ATV/

Noel Matthews-G8GTZ on "The GB3HV digital project – part 1"
<http://www.g7lwt.com/documents/datv/GB3HV%20digital%20article1.pdf>

OCARC newsletter DATV Introduction article on "ATV – the Digital Fork in the Road"
www.W6ZE.org/DATV/TechTalk74-DATV.pdf

OCARC newsletter DATV article "Planning a Digital-ATV Station"
www.W6ZE.org/DATV/TechTalk75-DATV.pdf

OCARC newsletter article "Understanding Symbol-rates, FEC, and RF Bandwidth for DVB-S"
www.W6ZE.org/DATV/TechTalk76-DATV.pdf

Jean-François Fourcadier-F4DAY on "The POOR MAN's DIGITAL ATV TRANSMITTER"
pagesperso-orange.fr/jf.fourcadier/television/exciter/exciter_e.htm

Rob Swinbank-MØDTS on details of "Poor Man's Digital ATV Transmitter – LIVE update"
www.M0DTS.co.uk/datv.htm

Nick Sayer-N6QQQ blog on "Putting together an ATSC DATV station"
<http://nsayer.blogspot.com/search/label/ham>

South West Herts UHF Group in UK
www.GB3BH.com

PE1JOK and PE1OBW on "The Ultimate Resource for Digital Amateur Television"
www.D-ATV.com

David Sparano on "WHAT EXACTLY IS 8-VSB ANYWAY?"
www.broadcast.net/~sbe1/8vsb/8vsb.htm

AGAF D-ATV components (Boards)
www.datv-agaf.de and www.AGAF.de

SR-Systems D-ATV components (Boards)
www.SR-systems.de

Typical Internet store for FTA DVB-S SetTopBox Receivers
www.GoSatellite.com