Digital Television – the new Ham frontier

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Introduction –
Digital television in the USA came into being commercially in the early 90's. Since then the official transition to all digital didn't take place till June of 2009. Amateur television started somewhere around 2000 mainly in Europe with on the air signals not appearing until around 2002 when some digital board sets became available. Since then amateur repeaters in Europe have been increasing in popularity but sadly lacking in the USA. In January of 2004 the ATCO Group in Columbus, Ohio installed a DVB-S digital output to their repeater which has been in service 24-7 since then. As of July 2009, the ATCO Group is the only one in the USA with a repeater digital ATV output.

The ATCO repeater digital output uses DVB-S modulation which we believe is the best choice for Amateur television. The following discussion details more fully why we feel it is best along with operational experiences to back it up. I know of no other group, USA or Europe, that justifies it with "in service" data. Therefore, we are able to back up our statements with results and not just theoretical details.

DATV advantages over analog.

- **Picture quality is near perfect.**
  Strong and weak signals all are "P5". That is a snow free signal. Analog amateur television signal strengths are indicated with the "P" system where P0 is a barely detectable signal and P5 is snow free. The signal strengths increase in 6dB steps from P0 to P5 so P5 is 6 x 5 = 30dB stronger than P0. That's for **ANALOG.** A digital signal that produces a blank receiver screen with a "P0" signal strength will produce a "P5" or snow free picture if it's about 1-2dB stronger. Therefore in the analog world if a signal 1-2 dB stronger than P0 was displayed, the viewer would see a barely discernable picture while in the digital world he'd see a snow free picture.

- **Noise and Multipath cancellation possible.**
  The DVB-S QPSK modulation scheme uses forward error correction to cancel the effects of atmospheric/man made noise and multipath (ghosting). The noise is handled by Viterbi and the multipath is handled by Reed-Solomon algorithms. These are highly complex but effective ways of handling the data streams but beyond the scope of this discussion. Since the DVB-S modulation scheme was intended mainly for satellite to ground communication, the multipath is minimal so correction requirements are also minimal and simple but adequate for ATV (Amateur Television) applications.

- **Noise reduction.**
  As mentioned above, the Viterbi coding algorithm reduces noise due to atmospheric and man made influences but is minimal. Here also, the Hams are willing to tolerate some noise disturbances in the picture. However, it doesn't show up as the typical noise flashes in the picture

seen on an analog screen. It will appear as either a momentarily frozen picture (not a problem for Hams) or as checkered squares scattered through the picture (again usually not a problem). So, as you can imagine, it would be a problem with a commercial broadcast signal but is quite tolerable for Hams!

- **Can occupy less bandwidth.**
  A commercial 8VSB digital broadcast signal occupies a fixed 6MHz bandwidth and not subject to modification. The DVB-S signal bandwidth, however, can be tailored to meet the users' requirements. Therefore it can be made wider or significantly narrower than 6MHz with corresponding tradeoffs. If a narrower bandwidth is needed, video quality will suffer and fast motion may pixelate. By "pixelate" we mean that checkered squares will appear in the picture where the data cannot be refreshed accurately. For most Ham applications, we are not showing video of race cars and the person "on camera" is usually not moving rapidly, so again, this is usually not a problem. We have found that a Forward Error Correction (FEC) value of about 2/3 and a symbol rate of 3.125 is adequate for normal motion with 2 video streams in a 4MHz channel. (More on FEC and Symbol rates later).

- **Less transmit power required than analog for same range.**
  Because the digital signal contains more data than an equal analog signal, less power is needed to transmit an error free signal. Also, the signal envelope contains more peak power spread out more evenly across the occupied bandwidth allowing more information within the power envelope. An analog signal has most of the power closest to the signal center carrier but the digital signal is spread out more evenly across the spectrum. As a result, the digital signal looks more square as viewed on a spectrum analyzer. As a rough rule of thumb, the digital signal transmit power can be as low as $1/10^{th}$ as the power of an analog signal for the same received signal quality. Example: The ATCO digital QPSK 3 watt 1245MHz signal is received about the same as its 30 watt 1260MHz analog signal. (Both signals use identical antennas located at the same elevation 10 feet apart).

- **It's neat to be on the cutting edge (bragging rights).**
  Last but not least, it's neat to be able to tell people that your signal is the latest digital technology coming from a home built Amateur transmitter. There are a number of added club members acquired just because of that fact. Everyone likes to be a leader, right?

DATV disadvantages

- **Most DATV is in Europe.**
  Up to this time, it is clear that the European Hams are the more creative ones in regard to DATV. They pioneered it in the early stages starting at the turn of the 21^{st} century. I don't know the real reason why but guess that they are still building their own equipment whereas many Americans have given in to simply buying what they need and simply "plugging it in" to get them on the air. That's not necessarily BAD but it DOES limit the DATV operation here in the USA.

- **Transmit boards are expensive.**
  Transmit boards are available from European sources but NOT CHEAP and as we all know USA Hams are not exactly that! The board sets usually will run over $1000 for a 2 watt signal! It is therefore clear to me that the Europeans who spent a few years writing and perfecting the needed

code want to be reimbursed for their effort. I can't blame them but it doesn't sit well with our "cheap US Hams" so to this date…no economical solution.

- **Transmit boards are difficult to build.**
  Well, not really, but the **hardware** is the easy part as a number of manufacturers have created individual IC's at reasonable prices but writing the **software** code for these is another matter. What we REALLY need is to have some experienced Ham software engineers knowledgeable with digital TV sit down and help write us some useable code for a board set. Creating the hardware around the code is "a piece of cake" but I don't know of anyone willing to take time away from their "real job" long enough to create useful software for the good of DATV.

- **Modulators require interlaced video.**
  This is not a major drawback but one must be aware of it. To my knowledge, the software written for all boards available now require full interlaced NTSC video for the MPEG-2 compression to take place without errors. Almost all cameras output interlaced video but ID generators DO NOT. The most common ID generator is the ElkTronics ID board used to generate the station ID for most ATV repeaters but it does not have interlaced video and as a result, the signal pixelates and freezes frequently making the signal almost unusable. I know of no commercially available interlaced video ID boards. As a result the ATCO group custom made one from a Sandisk picture frame board and loaded it with the needed video ID slides. This is not a serious drawback but the builder must be aware of it. Maybe future software designs will overcome this problem.

- **Transmit delay of 1 to 2 seconds.**
  There is about a 1 to 2 second latency delay during the MPEG-2 compression (transmitter) and decompression (receiver). Most of the time it is of novel interest being able to watch the analog transmission and then the digital transmission occur with a 1 to 2 second offset. However, if any linking between repeaters is anticipated with DATV signals, it may be very cumbersome when using full duplex for people at each end to wait a couple of seconds before responding to a given comment. (Full duplex will create a 2-4 second delay). However, that may be fun to watch also, so who knows, maybe it's more entertainment!

- **Ungraceful fade margins.**
  Analog has a graceful fade margin. That is, the picture is recognizable while noise and signal fading increase and decrease from "snow free" down to within about 3dB of disappearing altogether. Digital, however, is unforgiving as it stays absolutely snow free down to within about 1dB of the threshold. Therefore the digital signal will remain viewable longer, but when the "cliff effect" point is reached, the signal is totally gone with no visible traces of it. The corresponding analog signal may have excessive snow but viewable traces of the signal remain. So analog has a distinct Ham advantage when receiving a DX signal under rapid fading conditions.

Broadcast standards – overview - major standards

ATSC (8VSB) North America.
DVB-T (CODFM) Europe Terrestrial
DVB-C (QAM) Europe & USA cable (numerous variations)
DVB-H (QAM) Europe handheld
DVB-S (QPSK) Europe and USA Satellite

- **8VSB disadvantages**
  Modulation scheme is very complex
  Fixed 19.4 MegSymbol data rate. Bandwith is not modifiable
  Amplitude modulation (vestigial sideband) needs hi linearity amps
  If amps not linear enough – too many transmit errors & screen blanks
  Audio channel not receivable on some tv sets
  Ham band not available with standard unmodified tv's
    430-450 no good - cable setting in some tv's default to QAM
    902-915 no good – above tv tuning range & crowded with wi-fi
    1240-1300 no good – this is above tv tuning range
  Special receive converter required for Ham applications
  Cannot use when receiver is in motion (no mobile operation)

- **DVB-T disadvantages**
  Receivers not in use in USA
  Needs high signal to noise ratio receivers
  DVB-T set top boxes not available in US.

- **DVB-C disadvantages**
  No common standard. Many variants used by each cable company
  Common receiver not available

- **DVB-H disadvantages**
  No well defined standard
  No receivers available

DVB-S – Why is it best for D-ATV?

- **DVB-S Advantage Summary**
  Used Free-to-air Receivers are readily available
  Receivers are "cheap" - $10 to $50 from EBay
  New receivers are $125 at local satellite stores
  High linearity amplifiers not required to transmit error free signal
  If amps not linear – excessive transmit signal spectral regrowth occurs but minimal errors
  Inexpensive LDMOS "brick" amplifiers for transmit can be used and are easy to build
  Format has multipath cancellation adequate for Ham use
  Modulation method not subject to motion limits – tested OK for mobile
  Less bandwidth needed than others for acceptable picture
  Bandwidth is modifiable for motion/resolution tradeoff selections
  Multiple channels within common carrier possible
  Seems best for Ham space shuttle D-ATV communication

DVB-S details

- **Modulation method**
  QPSK (frequency modulation) is used exclusively here. QPSK (Quadrature Phase Shift Keying) basically means that the signal is phase (FM) modulated in 4 quadrants of 360 degrees to essentially contain 4 times the data as a simple FM signal.

- **Encoding**
  As in most other standards, MPEG2 is used here also for data encoding. Forward error correction is employed using Viterbi and Reed-Soloman coding to correct for noise and multipath effects. The degree of correction is selectable as needs dictate making DVB-S very desirable because it allows the user to vary it for various conditions.

- **Linearity requirements**
  Linear amplifiers in the transmit chain can become VERY expensive. Therefore it is important for Ham use to employ the transmission method most tolerant of non-linearities. DVB-S is it! Since the modulation method is frequency modulation, it is inherently insensitive to non-linearities. This is not entirely so but it is found that an amplifier can be close to its 1dB compression point before the error correction approaches its limit. This is HUGE as it opens up the transmitter design choice tremendously. Simple LDMOS "brick" amplifiers like the Mitsubishi RA18H1213G unit are ideal for use on the 1240-1300MHz band to get a 10 watt (average) digital signal from a 50 milliwatt source. That brick has a bias input allowing for adjustment of FM or linear operation making it easy to see what the limit is for a given configuration. Now, non-linearities DO cause other problems though. Each time the signal passes through an amplifier stage, it creates spectral regrowth in the output waveform proportional to the degree of non-linearity. These are sidebands above and below the main envelope at a reduced amplitude level. Therefore, although the signal has minimum errors, the overall bandwidth will be wider. This may be a problem in some cases where the allocated channel is defined or where it just makes sense to minimize spectrum interference. The bottom line is choose the highest linearity amp affordable then use a good interdigital type of steep skirted bandpass filter to remove the remaining sidebands.

- **Power level measurements**
  At this point it is worth noting that output power level measurements using a standard "Bird" wattmeter are NOT accurate. The output spectrum envelope is somewhat rectangular instead of sinusoidal so average power measurements do not apply. Because of this rectangular type of waveshape, most of the power is at peak values longer making measurements read lower than they actually are. If a bolometer type pickup is used, yet another value will be read. I personally feel that the only meaningful value is the actual peak reading obtained reliably with a spectrum analyzer. If you use a" Bird", I'd multiply its reading by about 2 to get the actual transmit power.

ATCO CLUB and REPEATER DETAILS

The ATCO Group Inc., originally organized in 1980, is located in Columbus, Ohio USA and serves approximately 85 ATV'ers within a 50 mile radius. It is our purpose to further the exchange of information and cooperation between members, promote amateur television knowledge, fraternalism and individual operating excellence and conduct activities that advance the ATV general interest and welfare.

- We operate an ATV repeater installed in the fall of 1994 that now has 5 outputs (427.25MHz AM, 1245MHz DATV (DVB-S), 1260MHz FM, 2433MHz FM and 10.450GHz FM) and 4 inputs (439.25MHz, 1280MHz, 2398MHz and 10.350GHz). The DVB-S output was installed January 2004 and has been in operation 24-7 since then. Continual work is being done to improve quality and features.

- We conduct weekly "net" meetings on 147.48MHz at 9:00 PM Tuesdays that serves to introduce newcomers, discuss ATV topics and announce news. It is the simplex "gathering spot" for audio activity with control capabilities for the ATV repeater.

- We publish a Newsletter 4 times a year containing local events, late breaking ATV news, construction articles, tips/techniques, meeting announcements and whatever else we can find that has ATV interest. The newsletter and other ATV topics can be viewed on our internet homepage at WWW.ATCO.TV.

- We help provide security video coverage each year for various local public events such as our annua Independence Day fireworks show (which draws over 500,000 observers), various parades, local air shows and observation video of airport disaster drill activity. Additionally, we provide local severe weather observation that helps identify potential damaging storms to the public.

- We have Spring and Fall Events where we gather to share ideas, plan future activities, enjoy free food, have door prizes (for everyone) and usually conduct a mini Hamfest with trunk sales in the meeting place parking lot. Between that, we normally have a few Pizza parties where we can have pizza while enjoying the companionship of others.

- Recently we began streaming our weekly Net meetings on the internet for the benefit of those beyond the metropolitan Columbus, Ohio area. All are welcome to join in with the discussions. Just tune in at WWW.BATC.TV , select “ATV Repeaters”, scroll down to WR8ATV and then click on “view stream”. There you can both see and hear us during the Net. We’ll be there every Tuesday from approximately 8:30PM EST or EDT till about 10PM or whenever the Net closes.

- We are working on a link to connect the Columbus and Dayton repeaters. We found an ideal site halfway between us (35 miles from Columbus and 30 miles from Dayton) that we have been working on for a number of years now. We had it operational before the Dayton repeater had to move sites and have since started over. We are considering a digital link now but are concerned about the latency issues. That is, there is a 1 to 2 second delay in sending and receiving the signal so a full duplex link may turn out to be difficult for acceptable communication. With a repeater link, the delay is effectively doubled because it occurs at both ends!

- **DVB-S Operational details**
  Our digital (DVB-S) 1245MHz signal has been operational since January 2004 with a 2 watt signal receivable within about a 20 mile range. Recently we added a power amp to boost the output to about 10 watts average (20 watts peak) extending it to roughly 40 miles. There are about 15 club members with digital receive capability using surplus “Free To Air” digital receivers obtained on Ebay for about $50 each. Some additional people have obtained various receivers from Ebay and elsewhere for $10 to $75. All have worked ok and have had no trouble locking onto our DVB-S signal using only a minimal loop yagi antenna mounted less than 30 feet in the air. I personally have a 20 element loop yagi mounted 30 feet up my tower permanently pointed to the repeater 15 miles away connected to 75 feet of 7/8” Heliax. In the shack I have a 2 way splitter with my analog receiver connected to one port and the digital receiver connected to the other. Tests have proven that there is about 10dB of excess signal received for P5 picture reception.

The transmitter DVB-S board set of choice is the Netherlands D-ATV boards. We use (2) encoder boards connected to a modulator board and then to a 5 milliwat transmitter board providing us with two channels of video. The 5 milliwatt signal is fed to a Kuhne Electronics ultra linear amplifier (we were told high linearity amps were a MUST at the time) costing about $500 alone. The Kuhne 2 watt output was connected to the antenna until recently where a Down East Microwave 1200 MHz 20 watt amp was added to produce a 10 watt (average by Bird) signal. That output is fed to a custom made interdigital bandpass amp with steep skirts. The 3dB down points give a total bandpass of 5 MHz. Using 3.125 megasymbol rate with a 1:2 FEC, our overall signal is about 4 MHz wide excluding the spectral regrowth sidebands. This correlates closely with the formula, ***signal bandwidth = 1.3 x symbol rate***. With the filter in place the resulting signal on a spectrum analyzer looks very clean with the regrowth signal down more than 50dB from peak carrier.

We have tested mobile operation with great success. The DVB-S modulation scheme is supposed to be reasonably insensitive to motion and we proved that it indeed is! The vehicle in motion was accelerated to about 50 MPH with no loss of signal. In fact, the normal signal flutter and fading was essentially very surprisingly non-existent. While traveling under a bridge underpass, the signal was maintained with only a momentary picture freeze unnoticeable if not looking for it. The normal analog mobile ATV signal flutter which was very annoying, was virtually gone with digital!

Finally, a word about why we ended up using 1245 MHz for our digital signal. We originally had our analog signal on 1250 and digital on 1260. One morning my wife answered the phone and told me, “YOU HAD BETTER TAKE THIS CALL”. It was the FCC from Detroit who had been tracking our analog ATV signal. It turns out that since our 1250 MHz signal identified with a bulletin board sequence for 4 minutes every half hour, it was interfering with the local Ohio Department of Transportation (ODOT) reception of a Russian GPS signal used in their surveying efforts. Since ODOT couldn’t find the interference source after 6 months of searching, they called the FCC. The FCC drove from Detroit to Columbus and found our signal source after about ½ hour. I was contacted and initially told that we were ok and operating within our assigned band legally. Later I was notified that because of a recent FCC clause saying that interference to Radio-Navigation was prohibited in the 23cm band, we had to vacate. We finally ended up with our analog signal on 1260 and the digital one on 1245 leaving 1250 clear. That was ok till I added the power amp. Now spectral regrowth extended the upper bandpass to 1250 and again caused them interference. (They were not shy about telling me so). After I added the interdigital filter, no phone calls! So, it’s a long story but worth telling because it demonstrates the real need for a good bandpass filter. I still tell others how we interfered with a Russian GPS Satellite! It sounds bizarre until you know the details.