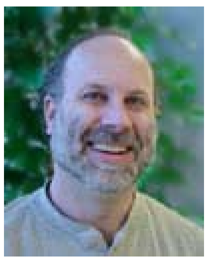
TAPR #111 SPRING 2010

PACKET STATUS REGISTER



President's Corner

By Steven Bible, N7HPR, President, TAPR

It is with great sadness that we report the passing of friend Dave Toth on February 26, 2010. Dave was President Emeritus of TAPR and also served as its President (2005-2009) and as a member of its Board of Directors (1987-1993 and 2004-2010). VE3GYQ will be best remembered for his dry sense of humor and his efforts to make TAPR's participation in the HPSDR project a resounding success. Dave will be sorely missed.

Dave's passing opened up a Board position. The TAPR Board voted to instate Dan Babcock, N4XWE, to the TAPR Board of Directors. Dan has been very active in the HPSDR project. He's devoted a tireless amount of effort to the testing many of the HPSDR boards. Dan is an engineer by training and profession. Please welcome Dan to the TAPR leadership.

We're getting ready for the 2010 Dayton Hamvention® and hope to see you there. If you have never been to the Hamvention, do yourself a big favor and save up your money and go at least once. You will not regret it. Not only will TAPR be there showing off all the projects we have been working on, but you can meet the people behind it all. Read about TAPR's activities elsewhere in this *PSR*.

If you can't make Hamvention, I hope that you can attend the 29th Annual ARRL-TAPR Digital Communications Conference (DCC) to be held in Vancouver, Washington, (just north of Portland, Oregon) on September 24-26, 2010. The DCC is much different than a hamfest as it is a technical conference. Talks and demonstrations are presented on the cutting edge of the Amateur Radio art.

If you can't attend, Gary Pearce, KN4AQ, has produced very professional DVDs of the 2008 and 2009 DCC. Check out the Amateur Radio Video News web site at www.arvideonews.com. You can get a flavor of what it's like.

Also, if don't have to be in attendance to submit a paper for publication in the proceedings. This is a great way to have your ideas published for posterity. It is very important for documenting the radio art that hams are best known for.

So the message this quarter is get out there! Whether it is a local hamfest, Hamvention, or DCC, get out there and meet folks and introduce yourself. We would love to have you!

– Steve, N7HPR

###

See You at the Hamvention in Dayton!

By Stan Horzepa, WA1LOU, e-mail wa1lou@tapr.org

42: Years I have been a licensed ham radio operator.

711: Miles between my house and the Hara Arena. Also, the place I stop to buy coffee between my house and the Hara Arena.

21: Times I have traveled between my house and the Hara Arena.

29,862: Miles between my house and the Hara Arena multiplied by 21 round trips.

If you get the drift of those numbers, you get the idea that I have an affinity for the Hara Arena, but the truth is that it is the annual event, known as the Dayton Hamvention, that occurs in and around the Hara Arena in mid-May that keeps me coming back.

The Hamvention is the biggest gathering of ham radio operators on the planet and I return as often as possible to discover what's up with the makers and shakers of our avocation.

As usual, TAPR has a full slate on tap for the Hamvention weekend (May 14-16, 2010).

Booths 455 through 458 in the Ball Arena of the Hara complex is where TAPR presents the latest advances in the state of the ham radio arts with an emphasis on software-defined radio (SDR) this year. TAPR is not "all show" either, as you will be able to purchase what we show at our booths.

The TAPR Digital Forum runs from 9:15 to 11:15 AM on Friday in Room 1 of the Hara Arena with the following schedule of luminaries making presentations, moderated by Mark Thompson, WB9QZB:

9:15 – TAPR Update by Steve Bible, N7HPR, and Scotty Cowling, WA2DFI

9:30 – WL2K Network and its RF Portals by Rick Muething, KN6KB, and Vic Poor, W5SSM

10:00 – TAPR Project Design for Manufacturing, by Scotty Cowling, WA2DFI

10:30 – Putting HPSDR on the Internet, by John Melton, G0ORX/N6LYT

11:00 – Wrap-up

Friday evening, TAPR and AMSAT hold their fourth annual banquet at the Kohler Presidential Banquet Center, Kettering, OH (just south of Dayton). Dr. Bob McGwier, N4HY, will be the after dinner speaker.

Doors open at 6:30 PM and a cash bar will be available. A buffet dinner begins at 7:15 and includes Salmon with Newberg Sauce, Marinated

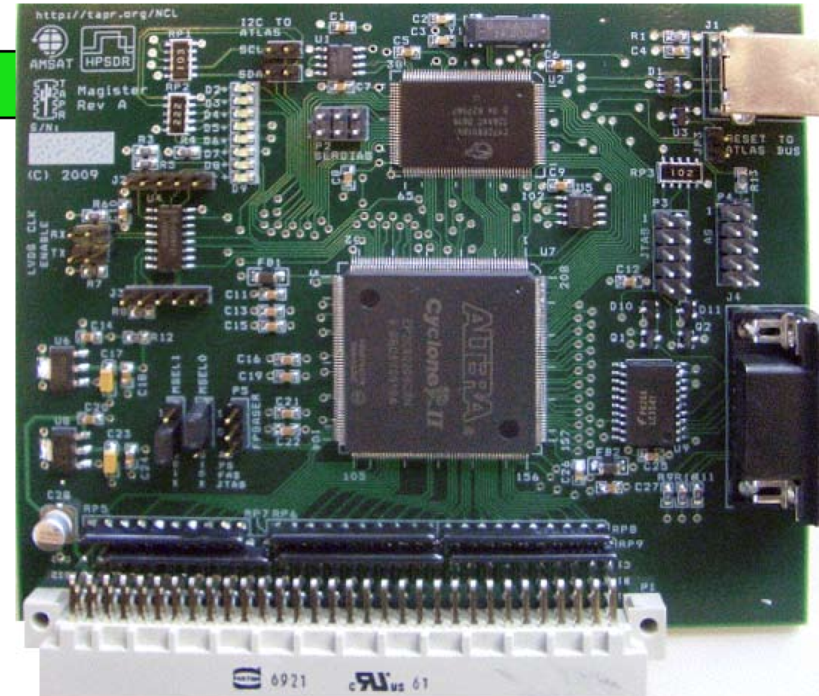
Roasted Garlic Rosemary Chicken Breast in Lemon Butter Sauce, Marinated Pork Loin, Scalloped Potatoes with Parsley, Normandy Blend Green Beans, Fresh Fruit, Green Salad, Pie, Iced Tea, Hot Tea and Coffee. (All items are capitalized because they are all delicious.)

You may make reservations for the 2010 AMSAT/TAPR Banquet online in the AMSAT Store at www.amsat-na.com/store/item.php?id=100158 or contact Martha at the AMSAT office from 10 AM to 6 PM EST/EDT at 301-589-6062 or toll free at 888-322-6728. You can pick up your reserved tickets at the AMSAT booth on Friday or at the door.

See you at the Hamvention in Dayton!

###

Magister Available Now



Magister is Latin for master. Magister is the master for HPSDR cards residing on the Atlas bus.

Magister performs most of the same functions as the discontinued Ozy. Functions missing are those used to interface to the SDR1000. Complete details on the differences follow.

Magister is an FPGA based interface controller card that provides a high-speed USB 2.0 interface for the Atlas bus, as well as limited additional I/O lines intended for radio control (e.g., bandswitching, CW paddle, etc.). It uses the same Altera Cyclone II FPGA as Ozy and is capable of running the current Ozy code (as of 19 September 2009).

The USB interface uses a Cypress FX2 chip, supporting full-duplex USB communications at greater than 30Mbps.

More detailed information is available on the Open HPSDR Wiki at http://openhpsdr.org/wiki/index.php?title=MAGISTER.

Magister Warranty

Magister is sold on an as-is basis without warranty of any kind. This is a low volume production, experimental item. TAPR is a small, not- for-profit organization of volunteers who have helped facilitate this project because we believe it is a cool thing to have. In order for TAPR to be able to offer this board at all, we must rely on the support of all users in the HPSDR community.

Support

The HPSDR Discussion List at http://openhpsdr.org/reflector.html will provide support for Magister.

Because TAPR is not staffed to provide support for Magister, and because the knowledge to support users resides with the developers and users on the HPSDR Discussion List, buyers should participate in that forum for support.

Firmware and software will be available for download from the HPSDR web site.

Ordering Information

The price for the assembled and tested Magister is $147 US for members of TAPR and $159 US for non-members plus shipping/handling if applicable.

Place orders on line at https://tapr.org/tapr_addorder.php?add=120

Acknowledgments

The Magister project team is: Lyle Johnson, KK7P, designer; Scotty Cowling, WA2DFI, parts, production, testing; Dan Babcock, N4XWE, testing; Nona Jurgens, parts procurement.

###

2010 TAPR-ARRL DCC in Vancouver, Washington

Vancouver, Washington is the site of the 2010 installment of the TAPR-ARRL Digital Communications Conference (DCC). More specifically, the Heathman Lodge at www.heathmanlodge.com, photo right, will host the DCC on September 24 through 26, 2010.

Vancouver, Washington is located on the southern border of Washington, just across the Columbia River from Portland, Oregon.

Call for Papers

Technical papers are solicited for presentation at the DCC. These papers will also be published in the Conference Proceedings (you do *not* need to attend the conference to have your paper included in the Proceedings). The submission deadline is July 31, 2010. Please send papers to: Maty Weinberg, ARRL, 225 Main St., Newington, CT 06111 or you can make your submission via e-mail to maty@arrl.org.

Papers will be published exactly as submitted and authors will retain all rights. View the paper submission guidelines at http://tapr.org/dcc.html#dccsubmissionguidelines

Tentative DCC Schedule

Friday, September 24, 2010

8:15 AM Conference Registration and Demonstration Room Open

9:00 AM Welcome and Introductions

9:30 AM Technical Presentations

Noon Lunch

1:00 PM Technical Presentations

6:00 PM Break

7:00 PM Social

11:00 PM Demonstration Room Closed

Saturday, September 25, 2010

7:15 AM Conference Registration and Demonstration Room Open

8:00 AM Welcome

8:15 AM Technical Presentations

Noon Lunch

1:00 PM Technical Presentations

3:15 PM TAPR Membership Meeting

6:00 PM Break

7:00 PM Dinner Banquet

11:00 PM Demonstration Room Closed

Sunday, , September 26, 2010

8:00 AM to Noon Sunday Seminar

Visit http://tapr.org/dcc.html for updates and registration information concerning the 2010 DCC.

###

TAPR President Emeritus Dr. David Toth, VE3GYQ (SK)

Dr David Toth, VE3GYQ, President Emeritus of TAPR, died on February 26 after a long battle with cancer. He was 55. A resident of Spencerville, Ohio, Toth served as a Director and Executive Vice President of TAPR in the 1980s and was elected President of the organization in September 2005. With his advancing illness, he decided not to stand for re-election last October and was instead named President Emeritus with Steve Bible, N7HPR, taking the reins as TAPR President.

"Dave was a great manager during his tenure at the head of TAPR," said ARRL Contributing Editor and TAPR Secretary Stan Horzepa, WA1LOU. "I give him a lot of credit for the success of TAPR's involvement in the high performance software defined radio (HPSDR) projects. The ham radio world has lost one of its best with VE3GYQ's passing."

An ARRL Life Member, Toth was a medical doctor who, despite his busy schedule, still made time to be an active amateur. In addition to experimenting with digital communications, he was an avid VHF contester. Licensed since the 1970s, Toth, a native of Windsor, Ontario, came to the US in 1993 to practice emergency medicine in Ohio. He was a partner of Premier Health Care Services in Dayton and worked at Lima (Ohio) Memorial Health System and St. Rita's Medical Center (also in Lima) until the time of his illness.

"Dave was an extreme pleasure to work with," TAPR President Steven Bible, N7HPR, told the ARRL. "Most people saw Dave's dry wit and humor, but underneath, he was also very passionate about TAPR and promoting the technical side of the Amateur Radio."

QST Editor Steve Ford, WB8IMY, remembered Toth fondly: "After years of telephone chats and e-mails, I finally met Dave Toth in the flesh at the 2006 ARRL/TAPR Digital Communications Conference in Tucson. Some say a brilliant intellect and a well-developed sense of humor are mutually exclusive, but Dave defied the stereotype. It was difficult to keep a straight face at the forums while Dave was muttering irreverent comments. He will be greatly missed."

Bob McGwier, N4HY, who worked with Toth on SDR and other digital communications projects, said that Toth was important to Amateur Radio "in so many ways. He was an early member of TAPR, a long time supporter of AMSAT and he gave of his time and talents to promote technical endeavors in Amateur Radio. Dave was an important player in the earliest days of packet radio in that he helped promote packet and supported it with on the air hardware, but he also participated in the development of a widely used BBS software suite that helped promote packet radio. As a board member and President of TAPR, he helped TAPR become the principal support for Open HPSDR, a project to promote the development of hardware and software for software defined radio use by Amateur Radio. TAPR kitted the hardware developments and made the widely available to amateurs everywhere. Dave was a great confidante, advisor, and friend. He will be sorely missed by all who knew him."

Toth was a private pilot for more than 30 years and an avid amateur astronomer. Since he was a young boy, Toth enjoyed looking at the night sky and reading about space and the stars. He had his own observatory that he opened up on clear nights. Toth was the founding member of the London (Ontario) Astronomy Club and served as its president; he was a member of the Royal Astronomical Society of Canada and belonged to the Lima, Dayton and Columbus Astronomy Clubs.

(Source: *ARRL Letter*)

###

Dan Babcock, N4XWE: New TAPR Board Member

Per Section 4.4 of the TAPR By-Laws, the TAPR Board of Directors elected Dan Babcock, N4XWE, to the TAPR Board to fill the vacancy left by the death of VE3GYQ. Dan's term on the board ends later this year.

Dan was first licensed as an Amateur Radio operator in 1975. Due to family responsibilities and other interests, he drifted away from ham radio for a few years and let his license expire. In 1989, he became very intrigued with amateur satellite communications, got relicensed and assigned the call N4XWE.

Over the past 20 plus years, he has been a member of AMSAT and TAPR. His main radio interests are software defined radio and digital mode HF operation. He is an avid kit builder and has constructed a number of HF transceivers, Softrock receivers, test equipment, HPSDR projects and other ham gear. His activities lean toward the technical more than the operating side of Amateur Radio.

Dan Babcock is a graduate of the Ohio State University College of Engineering. He has spent the majority of his working life in the aerospace industry as an engineer, marketer, and senior manager. For many years he was the chairman and president of an aerospace electrical components manufacturing company located in southwest Florida. He currently operates a manufacturer representation company that covers the states of Arizona, New Mexico, Utah and Nevada and specializes in turbine engine products, as well as engineered components for military and civil aircraft avionics.

Dan is the Vice-President of the Tonto Amateur Radio Association in Payson, Arizona and an active member of the TAPR manufacturing team.

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Join TAPR on Facebook and Twitter

By Mark Thompson, WB9QZB, e-mail wb9qzb@tapr.org

We created a new Facebook Fan page called *TAPR* at www.facebook.com/pages/TAPR/116614778354245. The TAPR fan page is linked to TAPR's Twitter account, *TAPRDigital*, so when you post an announcement on the *TAPR* Facebook Wall, a link to the announcement is automatically posted on Twitter.

We encourage everyone to follow TAPR on Facebook and Twitter to learn about:

- What's new at TAPR.
- Upcoming events at the Dayton Hamvention and the Digital Communications Conference.
- Other updates like *PSR*, projects, etc.

By the way, you can access the TAPR Twitter account at www.twitter.com/taprdigital

###

Six DVDs of DCC Released

For the second year, ARVN has covered the DCC, and once again filled six DVDs with technical presentations from the three-day event. Topics include equipment design and construction, Software Designed Radio, AMSAT / ARISSat, Packet and D-STAR networking, advanced APRS, and Digital ATV.

Details and a free preview video at www.arvideonews.com/dcc2009/

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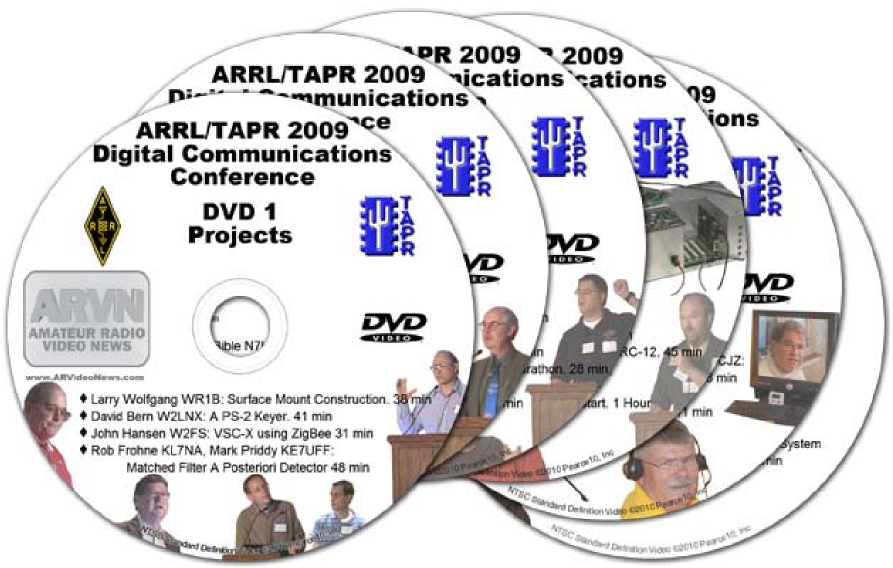

Get a New TAPR Badge

The brand new TAPR Badge with your name, call sign, and the TAPR logo is now available.

The price for the badge is $14 US for TAPR members and non-members plus shipping and handling.

To order online, visit
https://www.tapr.org/tapr_addorder.php?add=316

###

Advanced Amateur Radio Digital Infrastructure Techniques

By Erik Westgard, NY9D, e-mail ewestgard@att.net

The recent (early 2010) major earthquakes in Haiti and Chile are a reminder that many kinds of disasters and incidents will have little or no warning time. Military planners have for years called this "come as you are" (1), where you get to deploy and go to work with the resources, infrastructure and training you already have. We believe that an investment in modern fixed digital Amateur Radio infrastructure is the best use of our limited volunteer time and energy to support current and anticipated emergency communications needs.

Soon after 9/11/01, we starting thinking about what kinds of emergencies and incidents might require our communications assistance. Two scenarios came to mind right way- a mass evacuation of our largest metropolitan area (greater than 2M people) and a pandemic illness of some kind. Either of these cases would overwhelm our current capabilities, such as the daily phone and Morse Code traffic nets. Informal conversations with senior served agency officials confirmed this point of view.

In early 2002, we started constructing a statewide 1200 bps AX.25 packet radio backbone. We obtained high quality commercial/government transmitter sites for our equipment, which was designed for reliable operation. This provided an early focus for us, and a proof of concept for a standards based, collaborative model that avoided radio club politics and encouraged distributed local engagement.

Our largest annual area public service event, the Medtronic Twin Cities Marathon, and a wide area formal exercise with the Minnesota Department of Health reminded us that reliability was important.We have adopted a policy that no home stations would be part of any advertised backbone networks. And the probability of equipment failure required multiple levels of redundancy in all system elements. We have proven that three to five way active sparing can allow Amateur Radio networks to operate at commercial network reliability levels over long periods of time.

The announcement of D-Star equipment a few years ago was an important development for us. Our reliance on off-the-shelf AX.25 packet radio forced us to stay with a hard to use character mode interface, was limited in speed, and was in the same frequency bands as our voice equipment. We have rejected repeated calls (not interestingly from any of our served agencies) to use 802.11A/B/G equipment and the Internet for our backbone. Significant spectrum congestion, the short range design objectives of this technology, FCC Part 97 issues, and the need to provide plausible backup to the commercial Internet were some of the reasons.

In 2007, we got an Icom RP-1D/VS system and a series of Icom ID-1 radios. The RP-1D provides Ethernet over radio services, essentially encapsulating Ethernet frames in Amateur Radio call signs. We prototyped a web front end to our Linux missing persons tracking system (trivnetdb) and found it worked perfectly at around 90 kilobits/second. Our first year of live testing confirmed this, and we passed the hat and bought enough equipment to install five RP-1D systems on area rooftops.

Our systems are not currently linked to each other or Internet attached. The basic math behind reliability engineering states that parallel systems are more reliable than serial systems. (2)

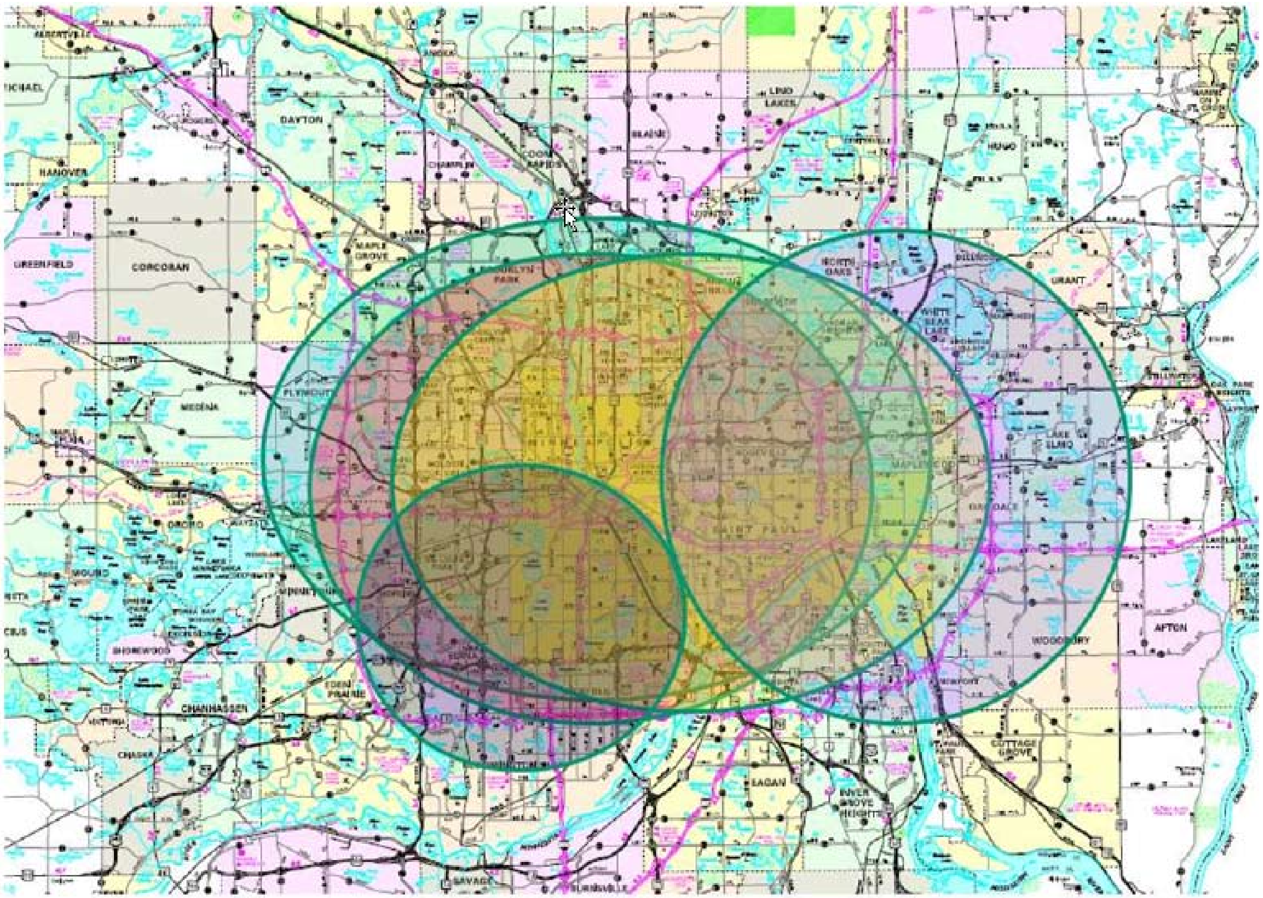

Figure 1. D-Star High Speed Data Coverage, November 2009

If we have our systems linked and or Internet attached, one hacker or failure could take out the entire network. If our systems are detached, and on five separate frequencies, five local, concurrent jamming transmissions would be required to take us off the air.

The current network coverage is represented by Figure 1. Additional transmitter sites are under contract, and the idea is to have any point in the entire seven county Twin Cities area covered by at least two and preferably three node transmitters. The systems with about ten watts of transmitter power each and antenna sites greater than 200 feet above average terrain give about ten mile range. This provides coverage with reasonable antennas, and permits multiple simultaneous user groups to leverage the systems. Faster radio data speeds and immunity from backbone overload have become useful features if we are to provide some backup to state of the art trunked public safety radio systems.

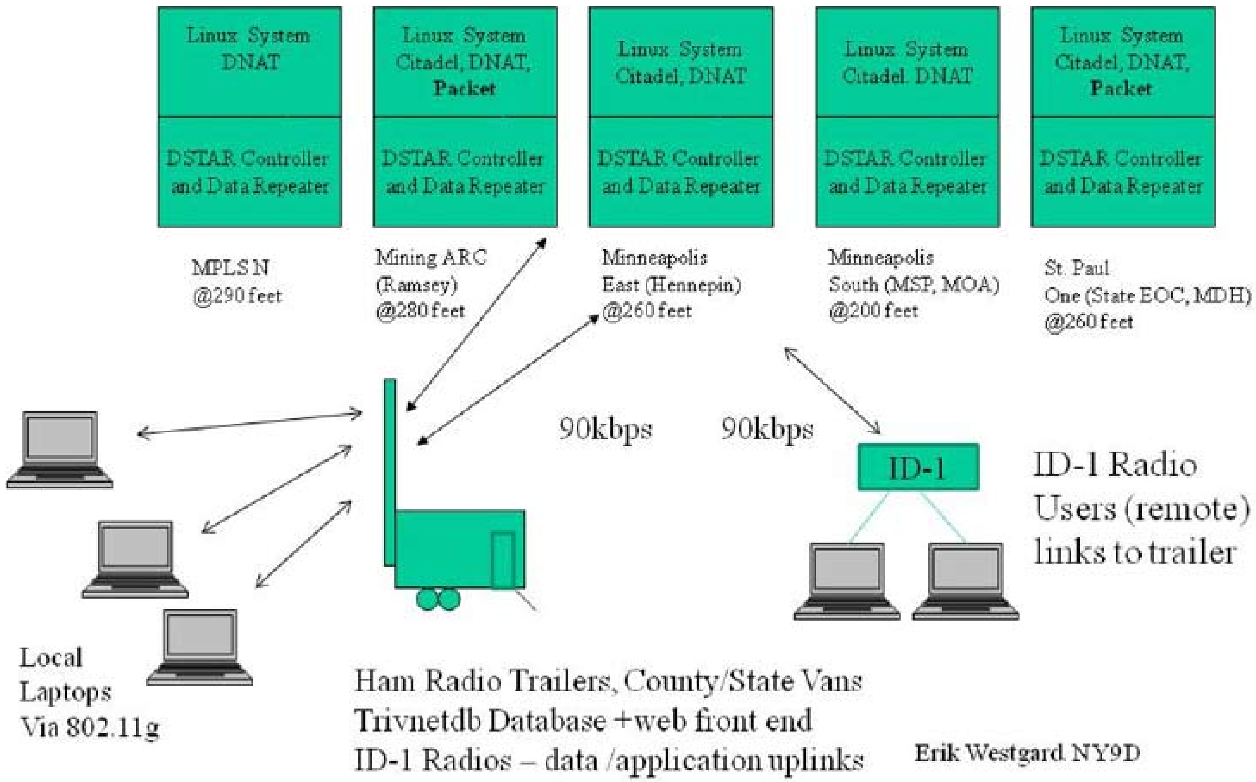

Figure 2. www.14567.org D-Star MSP, February 2010

Figure 2 provides a greater level of system detail. Each site has an Icom D-Star repeater controller and the Icom DD mode 1.2-GHz data radio module. Note the radios are simplex and each site operates on a unique frequency. Behind each repeater is a Linux appliance computer. We do not allow fans or conventional rotating computer disk drives at our transmitter sites, to increase reliability. We use flash-based disk drives, and minimize write activity to extend the life of these devices. Each Linux appliance has a tiny web site for ID-1 users on the standard ".20" node address per site and uses the Citadel mail and conferencing system. We also run DNAT, to allow multiple ID-1 radios to communicate with remote databases on other ID-1 radios.

Some sites have interfaces to AX.25 packet radio. This capability is trivial to add to Linux, and allows inter-network interoperability. We currently have a unique IP subnet for each site and DHCP. This could allow easy linking in the future. No unique software on ID-1 user computers is required. Our use of D-Star DD mode has been so successful, that we have retired AX.25 packet from active use except for long distance links.

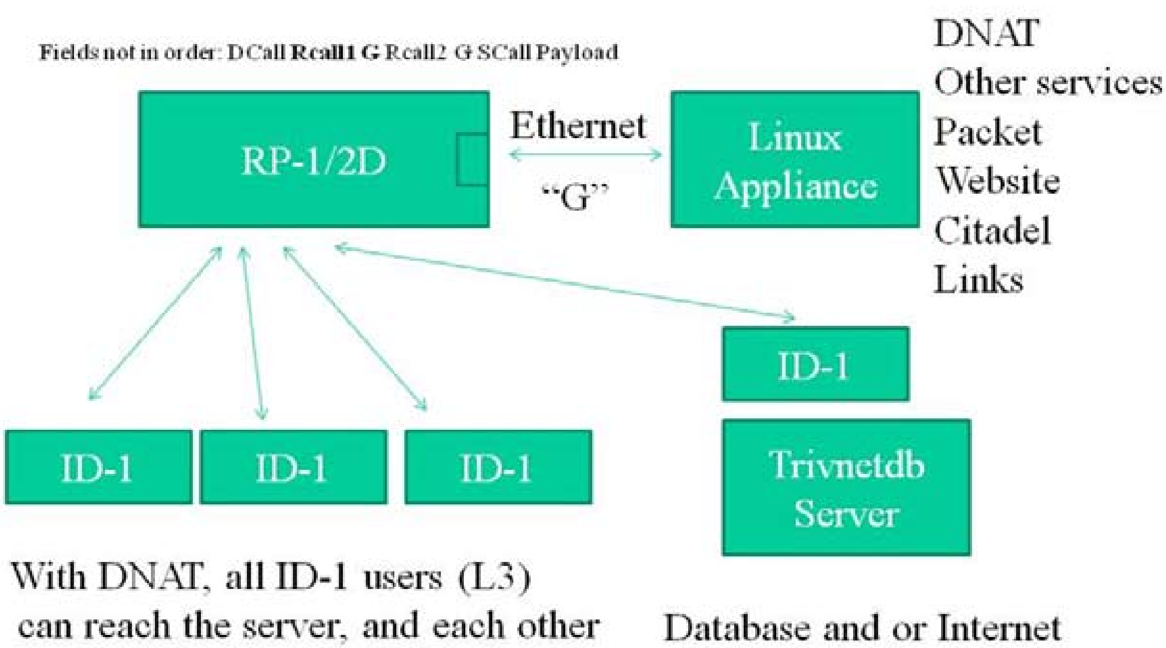

Figure 3. Icom D-Star DD Mode + DNAT. Stock DD RP unit is a simplex Ethernet bridge using call sign encapsulation. It supports one to one for ID-1s, but multiple connects to the repeater Ethernet. If you can run multiple subnets and DNAT on the back end appliance, multiple ID-1-ID-1 user (TCP/IP) sessions are possible.

Figure 3 shows the DNAT at a high level. The default behavior for ID-1 radios is to be able to communicate one to one in DD mode. Via a “repeater” they can also communicate one to one. Each ID-1 can also reach the Ethernet port on the repeater controller. If the Linux appliance keeps state on each ID-1 session, it can route between them. Our policy is that applications and databases outside of Citadel are located remote from the node sites. We use data trailers and communications vans, and run ID-1 radios as shared database uplinks. We find ourselves using satellite jargon a lot.

Recently we were asked to support a new urban running race in our area. We have 40 mostly FM voice repeaters to choose from, and the data planning was equally easy. We just located the start line, finish line, and medical aid stations on the map, and chose likely data machines to provide coverage. We think this would be the case in an actual emergency, as many of the area government communications operations centers and large mobile assets are equipped and tested with our system. We do not today need specific planning, training or prep time to support large scale “come as you” is events.

References:

1) “How the Army Runs,” US Army War College, 2009 edition, P97. Accessed 3/19/10 at www.carlisle.army.mil/usawc/dclm/linkedtextchapters/htar2009Ch6.pdf

2) “Building Resilient IP Networks” Kok-Keong Lee, Fung Lim and Beng-Hui Ong, Cisco Press, 2006, p.368

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Overview of DVB-S Modulation for Digital-ATV

By Ken Konechy, W6HHC, and Hans Hass, DC8UE, e-mail w6hhc@arrl.net and hanshass@web.de

DVB-S is a standard for commercial digital television broadcasting used throughout most the world (Europe, Asia, and Pacific). The "-S" suffix indicates that this particular standard is used for uplinks and downlinks of satellite television service. DVB-S is also one of the primary standards used by ham radio for Digital-ATV (DATV).

ATSC is the standard for commercial terrestrial digital broadcasting used in the USA and Canada. Choosing between ATSC and DVB-S technologies for DATV is an exercise in trade-offs.

DVB-S Standard: Pros

- Bandwidth can be as small as 2 or 3 MHz
- Cheap FTA Set Top Boxes (STB) on eBay
- Wide-spread experience and knowledge is provided by European hams on the Internet

DVB-S Standard: Cons

- Multipath interference immunity not as strong as ATSC, but plenty of FEC correction is available

ATSC Standard: Pros

- Best multipath interference immunity
- Cheap Set Top Boxes in USA
- 6 MHz bandwidth can support multiple video streams

ATSC Standard: Cons

- 6 MHz fixed bandwidth is no advantage over analog-ATV
- Dolby audio AC3 encoder licensing issue unfeasible for hams
- Current ham transmitter boards for ATSC cannot provide AC3 audio (Dolby)
- Use of substitute MPEG-2 audio does not work with ATSC STBs, but can (may?) work with cable-ready DTV receivers

Both authors have chosen DVB-S for their home DATV stations. Ken, W6HHC, further explains that he did not want to deal on a trial-and-error basis to see if equipment he purchased for receivers would really work with the current "MPEG-2 audio substitution" issue of ATSC DATV transmissions.

The purpose of this article is to introduce a few DATV DVB-S concepts that are typically not understood by hams and even analog ATVers.

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

- QPSK (Quadrature Phase Shift Keying) modulation
- MPEG-2 compression data rates for video
- FEC (Forward Error Correction) algorithms
- Knowing the video bit-rate to be supported
- Setting the net payload data bit-rate capacity for modulator
- Symbol rates
- RF bandwidth
- Effects of non-linearity in RF power amplifiers

This article will now walk through these various DATV factors and arrive at determining the resulting RF bandwidth for DVB-S.

Video Data-Rate and Compression

For DATV, the analog camera output is first digitized by the MPEG-2 Encoder board shown in Figure 1, and then compressed by the MPEG-2 algorithm. The reason the compressed video data rate shows a range of values in Table 1 is that the low value means little motion in the video scene and the higher value is required for video with a lot of motion. MPEG-2 encoding can be used in two modes: (a) constant output mode per frame with null packets inserted as needed and (b) variable data per frame.

a) Encoding for DVB-S uses constant data rate with null inserts as needed

b) Encoding for DVD burning uses variable data per frame

Notice in Table 1 that the digitized NTSC camera video data-bit stream is 168 Mbits/sec before compression, and MPEG-2 will reduce this to a rate between 1 and 3 Mbps, which is quite a reduction.

Table 1. Camera Video Data Streams & MPEG 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	15-60 Mbits/sec	compressed
HDTV MPEG-4	12-20 Mbits/sec	compressed

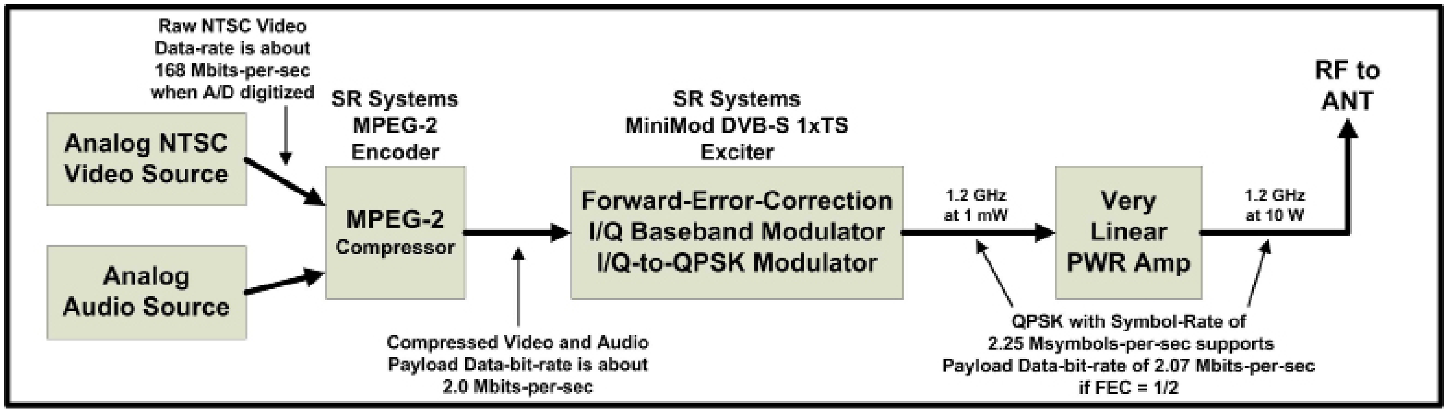

Figure 1. DATV Block Diagram Showing Various Data-Rates and Symbol-Rates for DVB-S QPSK

The MPEG-2 encoder we use makes a direct measurement of the compressed video rate not practical. Discussions with many hams in Europe reveal that they plan for the MPEG-2 output payload data-rate to be set typically between 2.0 and 2.5 Mbits/sec for PAL with excellent results for D1 video resolution. My own DATV tests show that settings of either 2.0 or 2.1 Mbps provide excellent video quality for NTSC.

FEC Inflation of Payload Data Stream Data-Rate

Forward Error Correction (FEC) is a technology that not only can detect errors on the received signal, but adds enough redundancy of the data so that it can correct several wrong bits. But there is a trade-off when choosing the amount of redundancy.

Since redundancy inflates the data rate of the output stream, the trade-off is between more redundancy or keeping the inflated data rate smaller. As we will see a little later in this article, the larger the inflated output 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, and the DATV receiver screen will go blank or freeze.

DVB-S commercial television standard uses a combination of two different Forward-Error-Correction (FEC) algorithms together in order to provide protection against noise errors and multipath 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. Theses 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. The second number ("2" in the case of configuration 1/2) is the number of output bits from the FECviterbi algorithm. So the MPEG2 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 FECviterbi 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. Its data stream "inflation rate" is 188/204. So for every 188 bits going into the FECreed-solomon algorithm, 204 bits come out for an additional FEC inflation of 8.5%.

Digital Modulation Symbols and Symbol-Rates

Digital modulation technology like BPSK (for example PSK-31), QPSK (Quad Phase Shift Keying – 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 2 lists out how many data bits can be packed into a symbol for several well known digital modulation technologies.

Table 2. Symbol Bit-Packing for Various Digital Modulation Technologies

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

Table 2 means that QPSK modulation will pack two data bits into each symbol being modulated. If we know the final output data bit-rate (we 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 Gross Data Bit-rate. For example:

Gross Data-Bit-Rate = 4.5 Mbits/sec

Symbol Rate Needed = 2.25 Msymbols/sec

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

Symbol-Rate Needed = NDBR / (Me x CRv x CRrs)

Where:

NDBR = Net Data Bit-rate (aka the information rate) Same as MPEG-2 output data rate in Table 1

Me = Modulation Efficiency (2 for QPSK in Table 2)

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

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

We will now calculate an example for QPSK where the output of MPEG-2 is 2.05 Mbits/sec and FECviterbi is set to 1/2.

Symbol-Rate Needed = 2.05 Mbits/sec
2 bits/symb * (1/2) * (188/204)

Symbol-Rate Needed = 2.05 Mbits/sec
0.921 bits/symbol

Symbol-Rate Needed = 2.23 Msymbol/sec

Confusion About The Word "Bandwidth"

While talking to hams in Europe about DATV repeater designs, we noticed that sometimes we were given unexpected bandwidths being used by the European repeaters. The Symbol-rates (S/R) being reported by the repeaters were always accurate (Symbol-rate is always a setting in the transmitter, so it is well known), but the RF bandwidth reported sometimes had an unexpected relationship to Symbol-rate. A little searching on the Internet (love Google and Bing search engines) showed that there are at least three popular ways methods of defining RF bandwidth for DVB-S.

- "minus 3 dB" bandwidth method
- "occupied" bandwidth method
- "allocation" bandwidth method

So if you were to ask three different hams "what DATV bandwidth are you using?", you may get three different answers when talking about the same DATV repeater!!!

The authors agree that the most important purpose of describing bandwidth for DATV hams is to provide a value that can be used for band-plan spacing and frequency coordination to avoid adjacent interference.

Now we will look at these three methods of describing RF Bandwidth for DVB-S (QPSK modulation).

"Minus 3 dB" Bandwidth Method

With this method, the bandwidth is measured at the points that are down 3 dB. This is a typical method for measuring an analog filter bandwidth and represents the "half-power point" if you are looking at voltage on a spectrum-analyzer.

Mathematically, BW-3dB ≈ S/R for this definition.

While the BW-3dB method is very familiar to analog engineers and analog ATVers, it is not very useful for DATV to define the bandwidth of a digital signal transmission link for two reasons.

First, a modulation with a digital-(pulse-)modulation signal produces a non-Gaussian signal-flank.

Second, you would not want to space several DATV stations "shoulder-to-shoulder" on their 1/2–power points, since significant power would overlap neighboring frequencies. This approach to spacing of stations would create potential receiving interference, especially if several DATV repeaters are located together on the same hilltop or tower and receiving antennas are pointing in the same direction toward adjacent DATV repeaters.

As a note, the bandwidth of the DVB-S carrier at the minus 3.8 dB points is approximately the same as the symbol rate (S/R).

"Occupied" Bandwidth Method

As defined by the commercial satellite standard, 3GPP TS 34.121, section 5.8, the Occupied Band-Width (OBW) is the bandwidth containing 99% of the total integrated power of the transmitted spectrum, centered on the assigned channel frequency.

Mathematically for hams: BWoccupied = 1.19 x S/R

How is the occupied bandwidth measurement determined?

During this measurement, a Gaussian filter with a bandwidth greater than 10MHz and a resolution bandwidth (RBW) of 30 kHz or less is used to measure the distribution of the power spectrum.

First, the total power found in the measured frequency range is calculated.

Then, starting at the lowest frequency in the range and moving upward, the power distributed in each frequency is summed until this sum is 0.5% of the total power. This gives the lower frequency value for measuring the bandwidth.

Next, starting at the highest frequency in the range and moving downward, the power distributed in each frequency is summed until 0.5% of the total power is reached. This gives the upper frequency value. The bandwidth between the 0.5% power frequency points is called the "occupied bandwidth."

While the "occupied" bandwidth spacing of repeater frequencies is better at preventing adjacent interference than "minus 3 dB" bandwidth spacing, it still lacks one feature. The spacing should have a little guard-band to allow for unplanned obstacles like signal-path nonlinearity, etc.

"ALLOCATION" BANDWIDTH METHOD

This method for describing bandwidth provides a little guard band between adjacent DATV signals. The allocation bandwidth for DVB-S is calculated as

BWallocation = (1 + Roll-off-Factor) x Symbol-rate

BWallocation = 1.35 x S/R

when using a 0.35 Roll-off-factor. The Roll-off-factor (as shown in Figure 2) controls the grade of the slope of a DVB-S signal-edge.

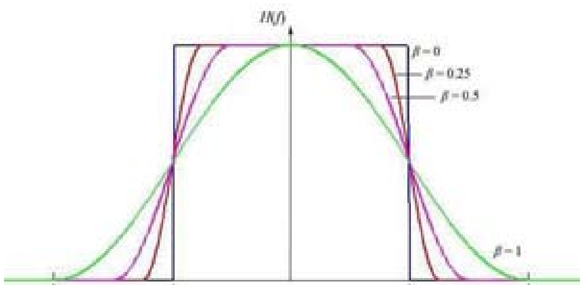

Figure 2. Different roll-off slopes for different Roll-off-factors

The "allocation bandwidth" is determined by the big commercial satellite-providers (like inside the Intelsat Earth Station Standard 420: (IESS420e.pdf) as an area, inside that the power-level will be not be lower than –26dB. There will be a filtering necessary on the signal borders (mostly performed by software), which takes care, that the borders rolls out weakly. The grade (slope) of this roll off will be described by the Rolloff-factor. It shows the relationship between half of the roll off area to half of the wanted channel-bandwidth.

DVB-S specifies the Roll-off-factor at 0.35. A raised cosine filtering at the edge region for the transmission path is required. The used filter generates in a first step only a root raised cosine shape. Only in combination with the same filtering inside the receiver you will get the wanted raised cosine form of the filter shape. After the transmitter, inside the "on the air" signal, you will find the larger signal shape (shown as the dotted larger signal shape (that is shown as the dotted line) in Figure 3.

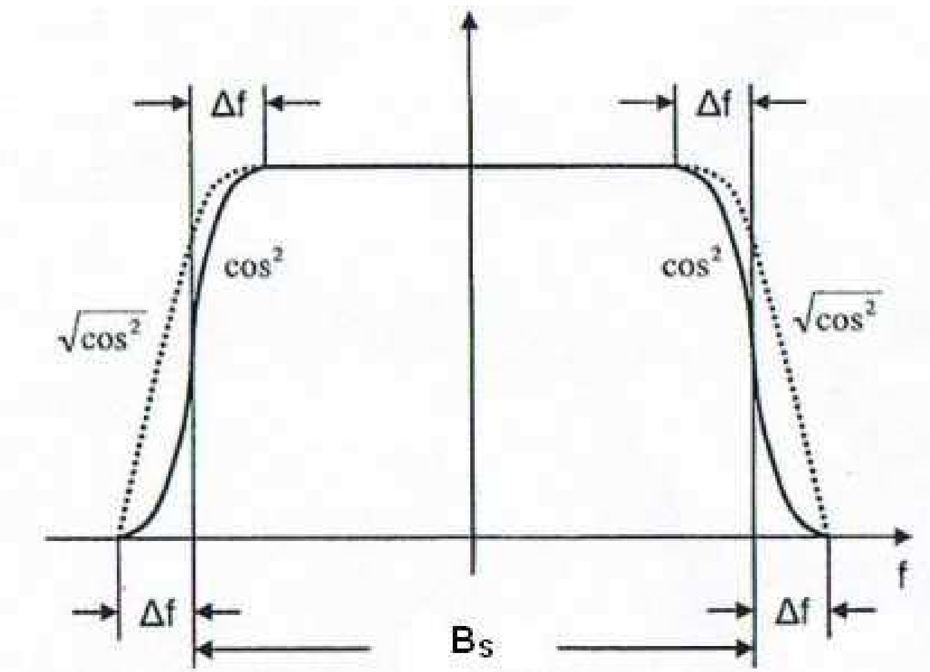

Figure 3. "On the Air" DVB-S signal has the shape shown as dotted lines

The DVB-S Standard uses a Roll-off-factor of 0.35 for video-transmissions and a Roll-off of 0.4 for data-transmission equipment. You may find that newer professional hardware utilizes a Roll-off-factor of 0.25.

The new DVB-S2-standard (for high definition TV - HDTV) also utilizes a Roll-off-factor of 0.2. This means, the DVB-S2 used bandwidth is only 20% bigger than the Symbol-rate. Hans, DC8UE, further explained that the DVB-S2 standard is now being used in Europe for transmissions from commercial broadcast-studios and also from an OB-van (outside broadcasting) to the uplink transmission center.

Figure 4 shows a DATV DVB-S QPSK signal using a 1.5 MSymbols/sec symbol-rate of (generated by a MiniMod). It shows clearly 2.025 MHz of used bandwidth.

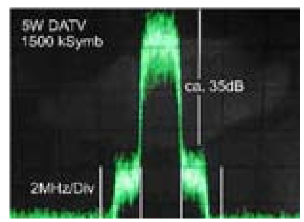

Figure 4. DATV QPSK signal at 1.5 M Symbol/sec produces 2.025 MHz of bandwidth

Below 35 dB you can see the additional shoulders, generated by intermodulation on the non-linear characteristic curves of the equipment being used. There is more on non-linearity, later in this article.

The "allocation bandwidth" is in practice really very useful to describe the real used bandwidth for spacing DATV repeater frequencies. However, for ham radio, Ken, W6HHC, prefers to "adjust" the allocation formula slightly to

BWallocation ~ = 1.33 x S/R

Ken explains that this "adjusted value" is less than a 2% error and is much easier to calculate in his head. The authors both agree that hams should only use the term BWallocation when they talk about DVB-S.

Choosing a Bandwidth

An advantage of digital ATV using the DVB-S standard is that the bandwidth can be narrower than the analog-ATV technology. Table 3 shows that a 3 MHz RF bandwidth can be achieved with plenty of error correction capacity (FEC = 1/2) by selecting a Symbol-rate of 2.25 M Symbols/sec.

Table 3. Net Data Bit-Rates for DVB-S at a Given RF Bandwidth

Modulation	FEC Coderate	DVB-S RF BANDWIDTH for DATV (RF BWallocation = 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

Notes:

1: NTSC Analog Camera produces about 2.0 Mbits/sec MPEG-2 output for ham radio type broadcasts

2: The Net Data Bit-Rate values inside the Table need to be at 2.05 Mbps or larger to support the expected camera and audio data rates coming from MPEG-2 encoder

3: The Net Data Bit-Rate values inside the table shown in RED (with strike-through) are Net Data Bit Rates that are too small to support the payload data stream.

Non-Linearity Effects on QPSK Bandwidth

Digital modulation using phase shifting (PSK) like BPSK or QPSK transitions from one state to another state. For QPSK, you are always in one of four states and your next transition can be to any of those four states, as shown in Figure 5.

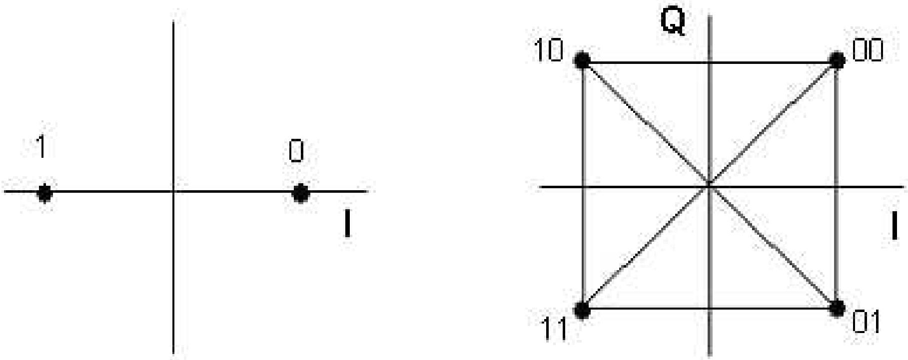

Figure 5. Theoretical transitions in the I-Q plane made by BPSK (on the left) with two states and by QPSK with four states.

However, non-linearity in the RF amplifiers can cause the received values of I and Q to contain errors from the theoretical. It is extremely important to avoid compression in the power amplifier and to operate the signal path and PA in a linear mode. Figures 6 through 9 show the effects of increasing non-linearity on the transition of states for QPSK modulation. Notice in Figure 9 that the non-linearity in the RF power amplifiers has brought the power level of shoulders much closer to the power level of the carrier. You can see in Figure 10 that the power levels of the shoulders have grown to 20 dB below the carrier. This will splatter power into adjacent frequencies outside of the allocated bandwidth.

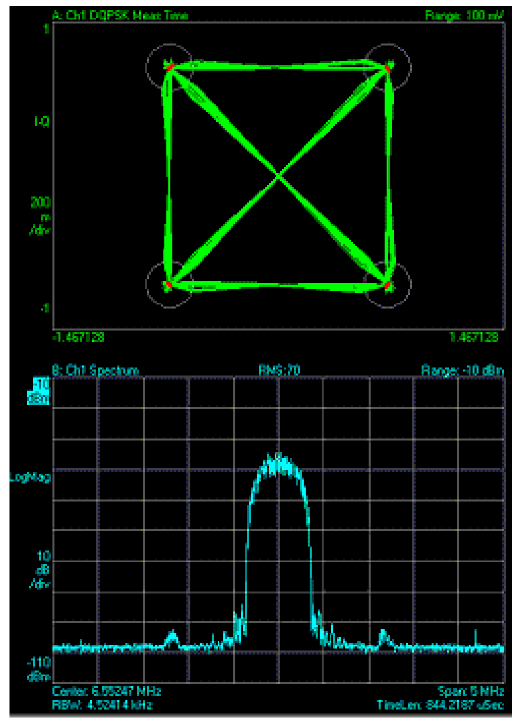

Figure 6. Real-world QPSK state transitions closely match theoretical with good linearity. (Photo courtesy of PE1JOK PE1OBW.)

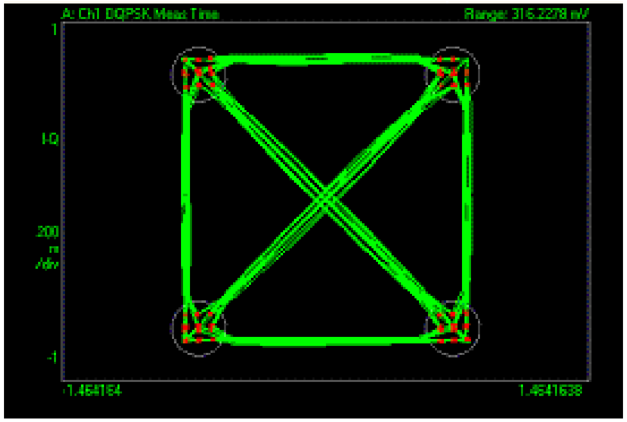

Figure 7. Increased non-linearity causes small errors in values of I and Q. (Photo courtesy of PE1JOK PE1OBW.)

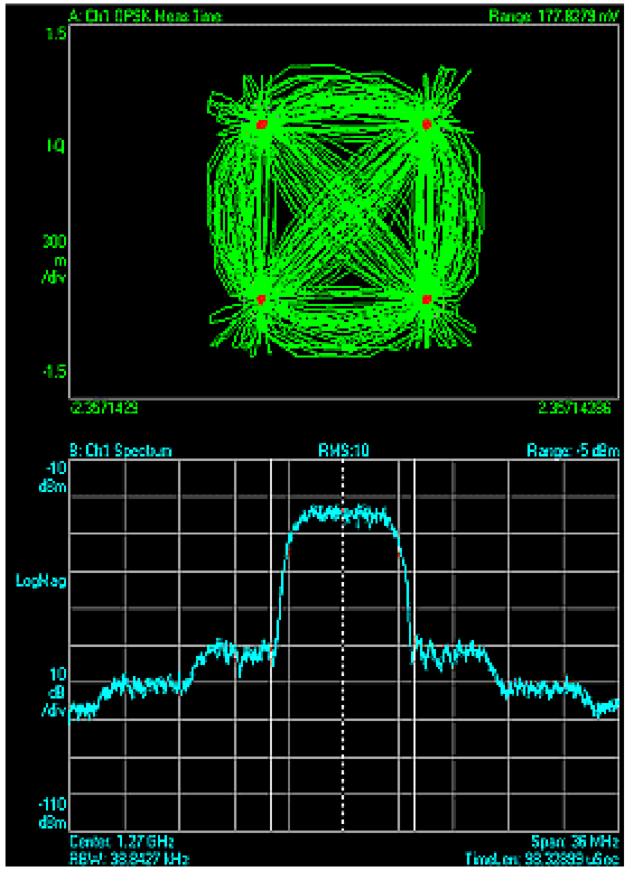

Figure 8. More amplifier non-linearity increases errors. (Photo courtesy of PE1JOK PE1OBW.)

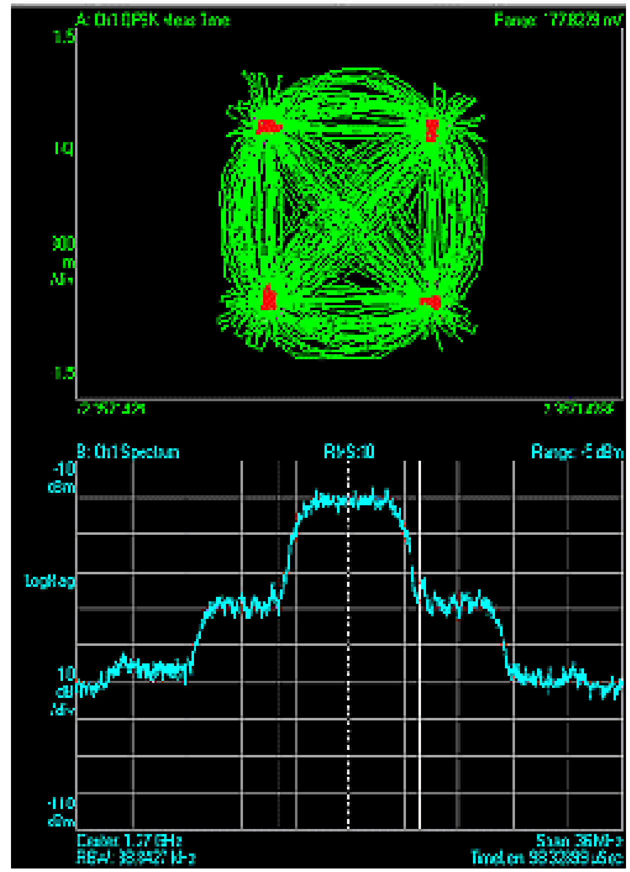

Figure 9. Amplifier non-linearity brings shoulders up. (Photo courtesy of PE1JOK PE1OBW.)

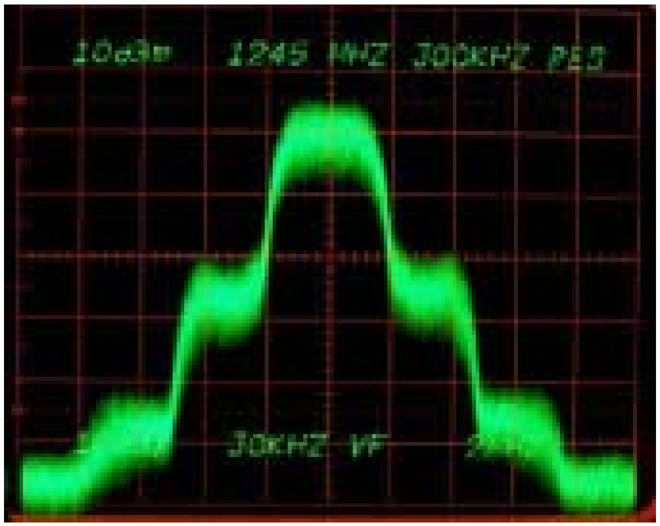

Figure 10. Spectral regrowth after amplification with shoulders now only 20 dB below the carrier. (Photo courtesy of Art, WA8RMC.)

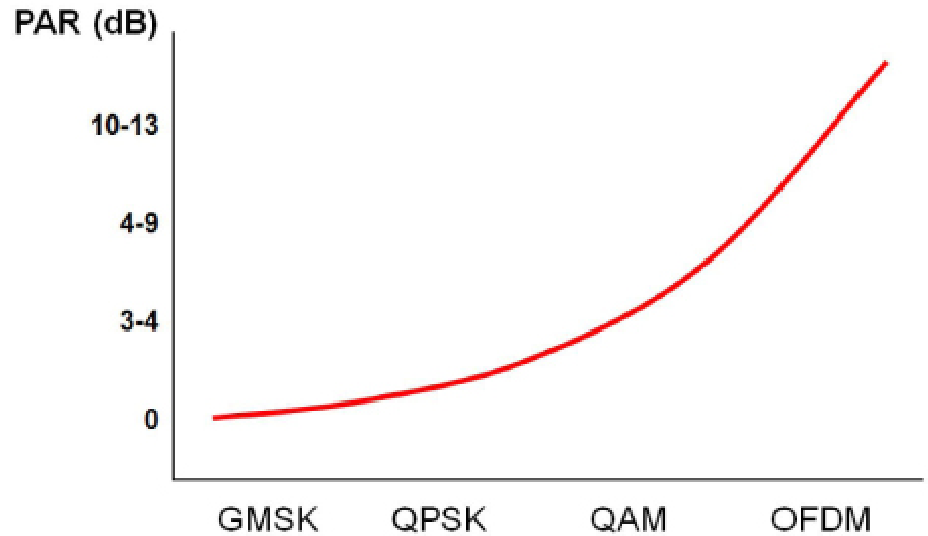

Figure 11. PAR for amplifier output power when processing signals with various digital modulation technologies. (Graph courtesy of Robert Green - Keithley Instruments, Inc.)

One concept that DATV hams need to understand with DATV amplification is that the DATV signal has a very high Peak-to-Average-Ratio, as shown as the parameter called PAR in Figure 11. So while the average power level may seem low, the peaks can be going into compression (or even flat-topping in saturation), hence non-linearity and hence stronger shoulder power levels.

Commercial satellite-uplink operators adjust their shoulders to be more than 26 dB below the main carrier. Likewise, it should be the duty of hams who operate DVB-S repeaters and transmitters to not allow the shoulders to get within 26 dB of their main carrier in order to avoid interference to nearby frequencies.

Interesting DATV Links

• Digital Video Broadcasting organization (DVB) – commercial TV – www.DVB.org

• Amateur Television of Central Ohio – www.ATCO.TV

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

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

• Jean-François Fourcadier-F4DAY on "The POOR MAN's DIGITAL ATV TRANSMITTER" – http://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

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

• Nick Sayer N6QQQ site for his future DATV repeater – www.N6QQQ.org

• Orange County ARC newsletter series of DATV articles – www.W6ZE.org/DATV/

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

• Kuhne Electronics (DB6NT) microwave RF Amplifiers – www.Kuhne-Electronic.de

• SR-Systems D-ATV components (Boards) – www.SR-systems.de and www.D-ATV.org

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The deadline for the next issue of *PSR* is August 15, so write early and write often.

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Packet Status Register

#111 Spring 2010, ISSN: 1052-3626

Published by

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Postmaster: Send address changes to TAPR, P. O. Box 852754, Richardson, TX 75085-2754. *Packet Status Register* is published quarterly by TAPR. Membership in TAPR, which supports the electronic publication of the *Packet Status Register*, is $25 per year payable in US funds.

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