

TechTalk #81

Understanding DATV RF Bandwidth for DVB-S

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In TechTalk76, Ken W6HHC explained how FEC and Symbol-rate affected the RF Bandwidth for the Digital Video Broadcasting (DVB) standard for satellite communications, called DVB-S. It turns out that defining RF Bandwidth for QPSK deserves some additional explanations in order provide a full understanding. Ken is pleased to be joined by Hans DC8UE for the creation of this month's TechTalk article. Hans had earlier helped Ken to understand the design of the popular DBØDHL DATV Multimedia repeater in Hamburg Germany...and has technical experience as a satellite-communications-engineer in a commercial TV-uplink-station.

Confusion about the word "Bandwidth"

When Ken-W6HHC and Robbie-KB6CJZ were talking to hams in Europe about DATV repeater designs, they noticed that sometimes they 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!!

Ken and Hans 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, $BW_{-3dB} \approx S/R$ 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 hill-top or tower so that 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: $BW_{occupied} = 1.19 \times S/R$

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 non-linearity, 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

$$(1 + \text{Roll-off-Factor}) \times \text{Symbol-rate}$$

$$\mathbf{BW_{allocation} = 1.35 \times S/R}$$

when using a 0.35 Roll-off-factor. The Roll-off-factor (shown in **Fig 1**) controls the grade of the slope of a DVB-S signal-edge.

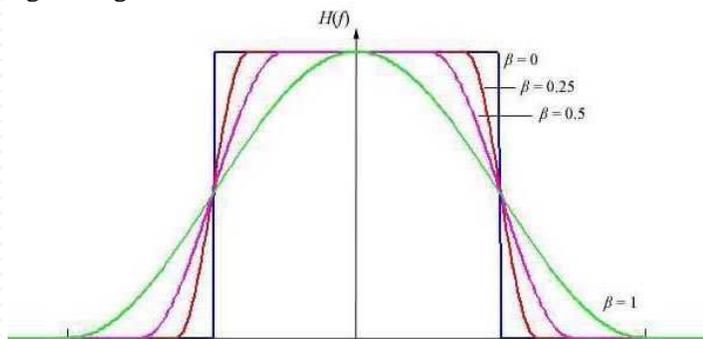


Figure 1 – Different roll-off slopes for different Roll-off-factors

The “allocation bandwidth” is determined by the big 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 line) in **Figure 2**.

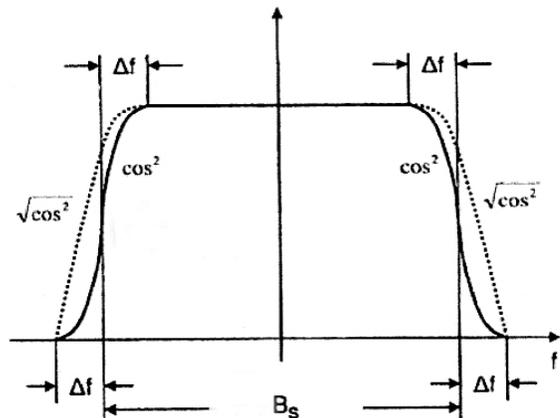


Figure 2 – “On the Air” DVB-S signal has the shape shown as dotted lines

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 on newer professional hardware utilize 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 up-link transmission-center.

Figure 3, on the next page, shows a D-ATV 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. Below 35dB you can see the additional shoulders, generated by intermodulation on the non-linear characteristic curves of the equipment being used. A value of 42 dB for the shoulder seems to be normal for the single MiniMod exciter. But, if a power amplifier is driven too hard, then the following PA can increase the power levels of the shoulders to extremely poor values.

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

$$\mathbf{BW_{allocation} \sim = 1.33 \times S/R}$$

Ken explains that this “adjusted value” is less than a 2% error and is much easier to calculate in his head. Both Hans DC8UE and Ken W6HHC agree that hams should only use the term **BW_{allocation}** when they talk about DVB-S.

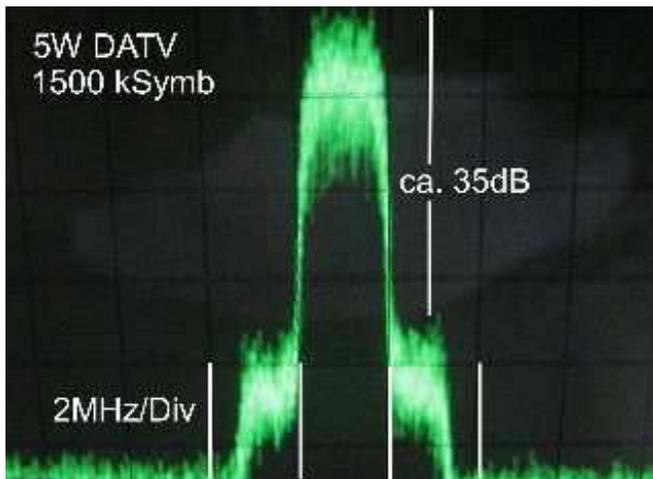


Fig 3 – DATV QPSK signal at 1.5 M Symbol/sec produces 2.025 MHz of bandwidth

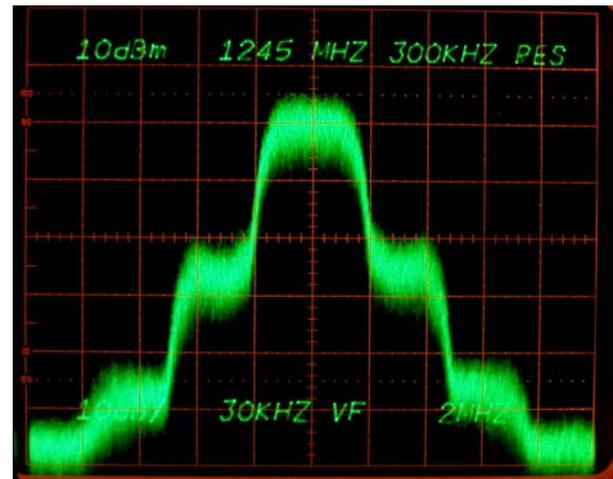


Fig 4 - Spectral regrowth amplified by different a PA with shoulders now only 20 dB below carrier (Photo courtesy of Art-WA8RMC)

Non-Linearity effects on bandwidth

It is extremely important, to avoid compression in the power amplifier and to operate the signal path and PA in a linear mode. As mentioned earlier, the shoulders in **Fig 3** (don't you think they look like "shoulders on a human"...on each side of the head??) can continue to grow in strength through non-linearity, including compression. While **Fig 3** shows the shoulders down about 35 dB below the carrier, **Fig 4** shows that the shoulders on this PA output are only 20 dB below carrier.

Hans DC8UE explains that when he made a transmission via a commercial satellite in the old (no longer used) analog FM-mode, they used the HPA (high power amplifier) in saturation (class-C). In the digital world with QPSK-modulation, they have to lower the power for class-A linear mode. That reduces the possible output power down to a level 4 to 5 dB below saturation. This reduction is called output backoff (OBO). During a terrestrial transmission (DVB-T RF-link), we have to reduce the OBO to a level 6dB below saturation, in order to hold the shoulders down.

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 PAR in **Fig 5**. So while the average power level may seem low, the peaks can be going into compression (or even flat topping in saturation), hence nonlinearity and hence stronger shoulder power levels.

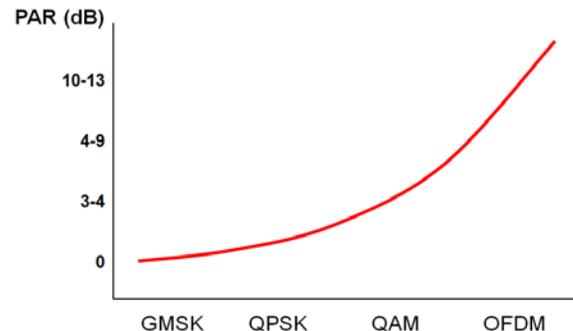


Fig 5 - PAR for amplifier output power when processing signals with various digital modulation technologies (Graph courtesy of Robert Green - Keithley Instruments, Inc.)

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 shoulders to get within 26 dB of their main carrier.

Interesting DATV Links

- AGAF D-ATV components (Boards) – see www.datv-agaf.de and www.AGAF.de
- SR-Systems D-ATV components (Boards) – see www.SR-systems.de and www.D-ATV.org
- British ATV Club - Digital Forum – see www.BATC.org.UK/forum/
- British ATV Club – select from about 25 streaming repeaters – see www.BATC.TV/
- German ATV portal for streaming repeaters and forum – see www.D-ATV.net/
- Amateur Television of Central Ohio – see www.ATCO.TV
- Orange County ARC newsletter entire series of DATV articles – see www.W6ZE.org/DATV/
- TAPR Digital Communications Conference free proceedings papers – see www.TAPR.org/pub_dcc.html
- Darren-G7LWT site for "DATV Primer" – see www.G7LWT.com/datv.html
- Nick Sayer N6QQQ site for his future DATV repeater – see www.N6QQQ.org
- Rob-MØDTS D-ATV site including details of F4DAY-design – see www.MØDTS.co.uk/datv.htm
- Ultimate Resource for Digital Amateur Television – see www.D-ATV.com
- RF Bandwidth online calculator for DVB-S/DVB-S2 – see www.satellite-calculations.com/Satellite/bitrates.htm