TechTalk115

DigitalATV – Overview of ITU-T_J.83B Protocol

by Ken W6HHC

Earlier OCARC TechTalk articles about Digital-ATV have provided details about how DVB-S protocol works, and went on to cover DVB-T and DVB-S2 protocols. DVB-S is still currently the most popular modulation standard being used by hams for DATV. This month I will look at some of the technical details of the DATV protocol defined by the ITU-T_J.83-Annex B standard.

The complete list of commercial origins of the DATV protocols being used by hams are listed below:

- DVB-S (satellite based)
- DVB-S2 (satellite for HDTV)
- DVB-T (terrestrial reception)
- ATSC (commercial terrestrial reception in US)
- ITU-T_J.83-Annex B (US/Canada cableTV)

ITU-T_J.83B

The ITU-T_J.83-Annex B protocol (I've shortened to ITU-T_J.83B) is commercially used by the US/Canada cableTV industry. This standard is very closely related and similar to the DVB-C protocol used in Europe and most of the world for cable TV. One main attraction of ITU-T_J.83B for hams is that several cable channels can fall directly on the 430 MHz ham bands. Therefore a terrestrial transmission by hams can be received directly to a cable-ready TV without adding any special receiver cost (aka more money). Just connect an antenna and tune your TV to the right channel. This is the nice attraction of the old analog-ATV approach on 430 MHz band.

ITU-T_J.83B for the cable world is designed to work with strong signals and a low noise environment. The main issue with ITU-T_J.83B when used by hams in a terrestrial mode (over the air – OTA), is that the environment can change to weak signals and lots of noise. That is: the received S/N gets much worse when you leave the cable environment.

Typical Transmitter Block Diagram

Fig01 is a block diagram of an ITU-T_J.83B basic ham station for DATV using QAM64 modulation to transmit a full HD video. Hams typically use MPEG-4 encoding to achieve enough data compression to fit a full 1080i high definition signal into a 6 MHz bandwidth. Typical manufacturers of ITU-T_J.83B exciters used by hams (mainly here in USA) are the Drake (model DSE-24) and Thor (model H-VQAM-SD). Typically a HDMI connector is available for HD cameras to be plugged in and composite video connectors (RCA jacks) are available for NTSC cameras and Standard Definition (SD) using MPEG-2 encoding. The DATV receiver is a commercial "cable-ready" TV set tuned to the 420-430 MHz USA cable TV channels 57-60 that overlaps the ham radio 70 cm band.

- 421.25 MHz CH-57
- 427.25 MHz CH-58
- 433.25 MHz CH-59
- 439.25 MHz CH-60

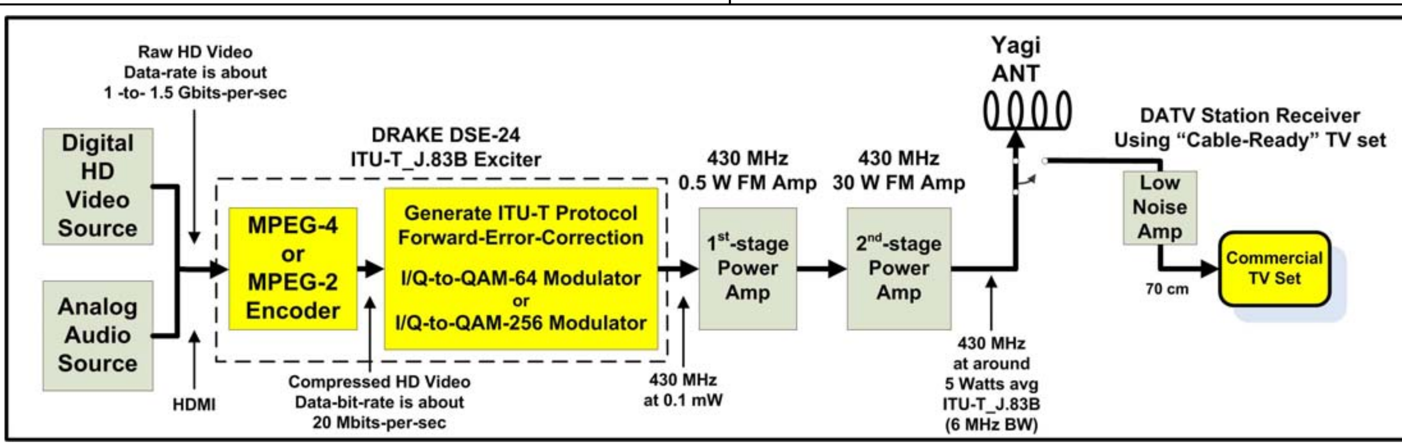

Figure 1 – Block Diagram of Basic ITU-T_J.83B Station for DATV

Table 1 – Camera Video Data Streams and MPEG-2 / MPEG-4 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
NTSC H.264/MPEG-4	~1.5 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 H.264/MPEG-4	12-20 Mbits/sec	compressed

Video Data-Rate and Compression

For HD DATV, a digital camera output is compressed using MPEG-4 encoding (aka H.264 and even sometimes called Advanced Video Coding - AVC). This encoder CODEC provides more compression of the video than the older MPEG-2 CODEC. For SD DATV, the analog NTSC/PAL camera output is first digitized by the optional MPEG-2 encoder shown in **Fig 1**, and then compressed by the MPEG-2 algorithm. The reason the compressed video data rate varies in **Table 1** is that the smaller value means little motion in the video scene and the larger value means a lot of motion. H.264/MPEG-4 can reduce the bit-rate by a factor of 50% over the older MPEG-2.

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 band-width. 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 or pixelate.

The FEC technology used by the ITU-T_J.83B protocol is that same as used by DVB-S protocol. That is: the two FEC algorithms are the Viterbi coding technology and Solomon-Reed. The puncture coding value used by ITU-T_J.83B DATV is not selectable and was difficult for me to pin down in the standard, but Ron W6RZ explained to me that the Viterbi FEC is 14/15. The total FEC overhead produced, Ron W6RZ explained, is approximately 11%. That translates into the MPEG-4 "payload" video data rate of about 20 Mbits/sec increasing to a "gross data rate" to a value of about 22.2 Mbits/sec that has to be encoded into encoded into the Symbol-Rate (SR) stream.

Digital Modulation Symbols and Symbol-Rates

Digital modulation technologies like BPSK (an example is PSK-31), QPSK (Quad Phase Shift Keying), 8PSK, 32APSK (Amplitude and Phase Shift Modulation), and QAM-64 (Quadrature Amplitude Modulation) with 64 "constellation points" have the ability to put more information into a more 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
8PSK	3
8-VSB	3
QAM-16	4
32APSK	5
QAM-64	**6**
QAM-256	**8**

ITU-T_J.83B protocol allows the use of two digital modulations: QAM-64 that packs 6 bits of data into each symbol transition and QAM-256 packs 8 bits of data into each symbol transition.

Figures 2 and **3** shows a comparison of the more simple QPSK modulation constellation and the much more complex QAM-64 constellation.

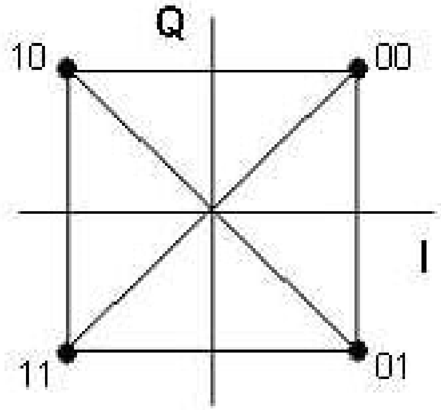

Figure 2 – The modulation constellation of QPSK used in DVB-S packs 2 bits of data in each symbol transition

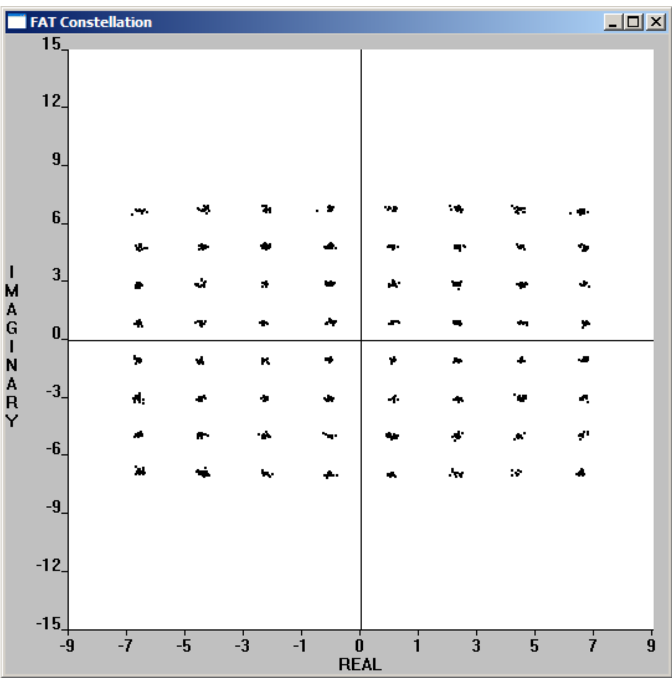

Figure 3 – The more complex modulation constellation of QAM-64 used in ITU-T_J.83B packs 6 bits of data into each symbol transition
(courtesy of W6RZ)

The complexity of a digital modulation scheme like QAM-64 allows much more data to be carried in a defined RF bandwidth…but also carries a penalty in signal robustness. The greater the modulation complexity…the greater the signal to noise ratio (SNR and aka C/N) needs to be. **Fig 4** compares the SNR needed to receive four different digital modulations , including QPSK and QAM-64. Even though this analysis is looking at COFDM world, it clearly shows that QAM-64 is less robust than QPSK. I think it is very easy to envision that the QAM-256 modulation would carry an even greater SNR robustness penalty (requires 8 dB more).

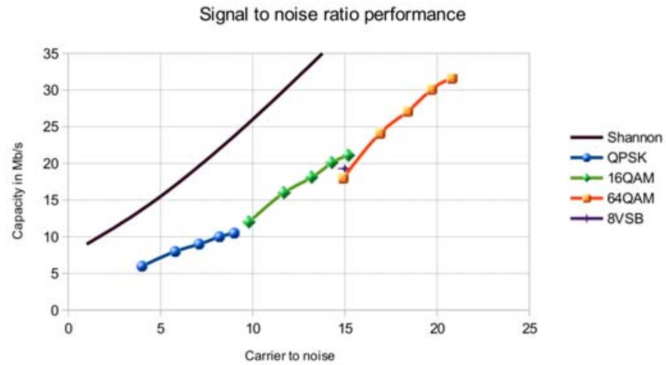

Figure 4 – A comparison of SNR of four different modulations including QAM-64 and QPSK shows the signal robustness penalty of complexity
(courtesy of ZL1WTT)

ITU-T_J.83B Bandwidth

The ITU-T_J.83B standard defines the RF bandwidth as 6 MHz wide "channels". In a manner similar to DVB-S protocol, the RF bandwidth of an ITU-T_J.83B transmission is defined by its Symbol Rate (SR). That is:

RF_{bw} = SR x 1.18 (roll-off factor)

So if we have a 6 MHz bandwidth, the Symbol Rate should be approximately:

SR = 6.0 MHz / 1.18 = 5.057 MSymb/s

The "gross data-rate" at this SR would then be ~30.3 Mbps. This is enough to carry a HD signal using MPEG-4 encoding. Ron W6RZ pointed out to me that: "At the 26.97 Mbps TS rate, you could easily have a 26 Mbps video stream (or two HD program streams at around 13 Mbps each)".

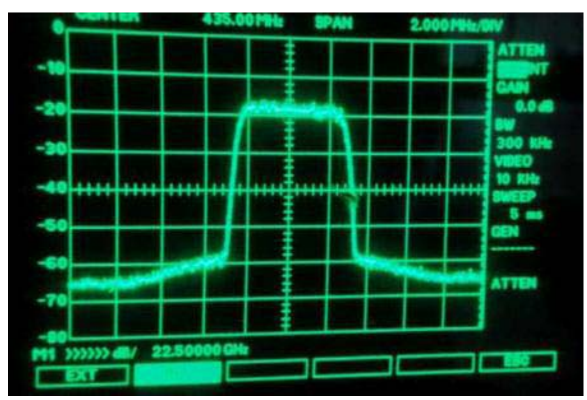

Figure 5 – A spectrum analyzer view of an ITU-T_J.83B QAM-64 transmission "haystack" on the 70 cm band
(courtesy of WA6SVT)

The cable-ready TV receivers are set-up to receive transmissions on the pre-defined set frequencies. These channels are spaced 6 MHz apart. I have not heard of any hams being able to receive QAM-64 transmission bandwidths more narrow than 6 MHz on commercial TV sets.

Status of Ham ITU-T_J.83B DATV

One of the pioneers in US for DATV using the ITU-T_J.83B protocol is Jim KH6HTV. He participated in setting a DX record of 121 KM on the 70 cm band using QAM-64. Two ATV repeater groups in US have tested adding the ITU-T_J.83B protocol to their DATV repeaters. The ATN group in Southern California tested a 70 cm DATV repeater on Mt Wilson, where uplinks were received via analog-ATV and downlinked using DATV as W6ATN. The ATCO group in Columbus Ohio (they installed the first DVB-S DATV repeater in USA in 2004) also installed ITU-T_J.83B protocol to their WR8ATV DATV repeater downlink on 70 cm.

When I first started preparing for this article, I contacted Mike WA6SVT of the W6ATN repeaters and also contacted Art WA8RMC of the WR8ATV repeater to get feedback and obtain their insights on using ITU-T_J.83B for a DATV repeater. To my surprise, I learned that both repeater groups had stopped using the ITU-T_J.83B protocol and were installing DVB-T down-links. The W6ATN tests had signal robustness difficulty being received across the large Los Angeles basin into Orange County.

Art WA8RMC explained that “nobody was using the ATCO ITU-T_J.83B downlink”. Art went on to report that: ”I could see the CATV QAM signal but even though a vertically polarized signal was being sent, I could only receive it with my horizontally polarized antenna. After some additional testing and assumptions we concluded, ‘The QAM signal suffers from multipath cancellation issues which is minimally accommodated in the receiver. Also, minimal FEC is applied to the transmitted signal because it is not needed when in a cable.’ ATCO concluded that because of multipath issues, DATV using this mode is not practical“. Jim KH6HTV has also redirected his DATV interests and activities to DVB-T protocol because “…it far outperforms the CATV DTV 64QAM. I only used the QPSK modulation because of its superior receiver sensitivity. I found I was still able to transmit very acceptable, HD 1080p pictures using simpler QPSK compared to QAM.”

Conclusion

The ITU-T_J.83B approach to DATV offers “easy appliance-like installation” for DATV and also offered the glamor of being able to transmit full 1080 HD video. But, the penalty of the higher C/N requirements of the QAM-64 modulation is too large…compared to other now-available alternatives. I do NOT see ITU-T_J.83B protocol becoming a significant factor for DATV in the future.

Acknowledgement

I want to thank Ron W6RZ for providing some of the mathematical details and obscure ITU-T_J.83B protocol specification details for this article.

Useful URLs

- ATCO - Amateur Television of Central Ohio – see **www.ATCO.tv**
- British ATV Club - Digital Forum – see **www.BATC.org.UK/forum/**
- CQ-DATV online (free monthly) e-magazine – see **www.CQ-DATV.mobi**
- DATV-Express Project for DATV – see **www.DATV-Express.com**
- DigiLite Project for DATV (derivative of the “Poor Man's DATV” design) – see **www.G8AJN.tv/dlindex.html**
- KH6HTV Application Notes DATV with ITU-T_J.83B and DVB-T – see **http://KH6HTV.com/application-notes/**
- Orange County ARC entire series of newsletter DATV articles and DATV presentations – see **www.W6ZE.org/DATV/**
- TAPR Digital Communications Conference proceedings (free downloads) – see **www.TAPR.org/pub_dcc.html**
- Yahoo Group for Digital ATV - see **groups.yahoo.com/group/DigitalATV/**