DVB-S2 / RCS

The DVB-S2 system has been designed for several satellite broadband applications:

- Broadcast services for standard definition TV and HDTV;
- Interactive services, including Internet access, for consumer applications;
- Professional applications, such as Digital TV contribution and News Gathering, TV distribution to terrestrial VHF/UHF transmitters;
- Data content distribution and Internet trunking.

It is based on a "tool-kit" approach which allows us to cover all the application areas while still keeping the single-chip decoder at reasonable complexity levels, thus enabling the use of mass market products also for professional applications.

The DVB-S2 standard has been specified around three key concepts:

a) Best transmission performance,
b) Total flexibility and
c) Reasonable receiver complexity.

To achieve the best performance complexity trade-off, quantifiable in about 30% capacity gain over DVB-S, DVB-S2 benefits from more recent developments in channel coding and modulation. For interactive point-to-point applications such as IP unicasting, the adoption of the Adaptive Coding & Modulation (ACM) functionality allows us to optimize the transmission parameters for each individual user on a frame-by-frame basis, dependant on path conditions, under closed-loop control via a return channel (terrestrial or by satellite): the result is an even greater gain of DVB-S2 over DVB-S.

DVB-S2 is so flexible that it can cope with any existing satellite transponder characteristics, with a large variety of spectrum efficiencies and associated C/N requirements. Furthermore, it is not limited to MPEG-2 video and audio coding, but it is designed to handle a variety of advanced audio video formats which the

DVB Project is currently defining. DVB-S2 accommodates any input stream format, including single or multiple MPEG Transport Streams, continuous bit-streams, IP as well as ATM packets.

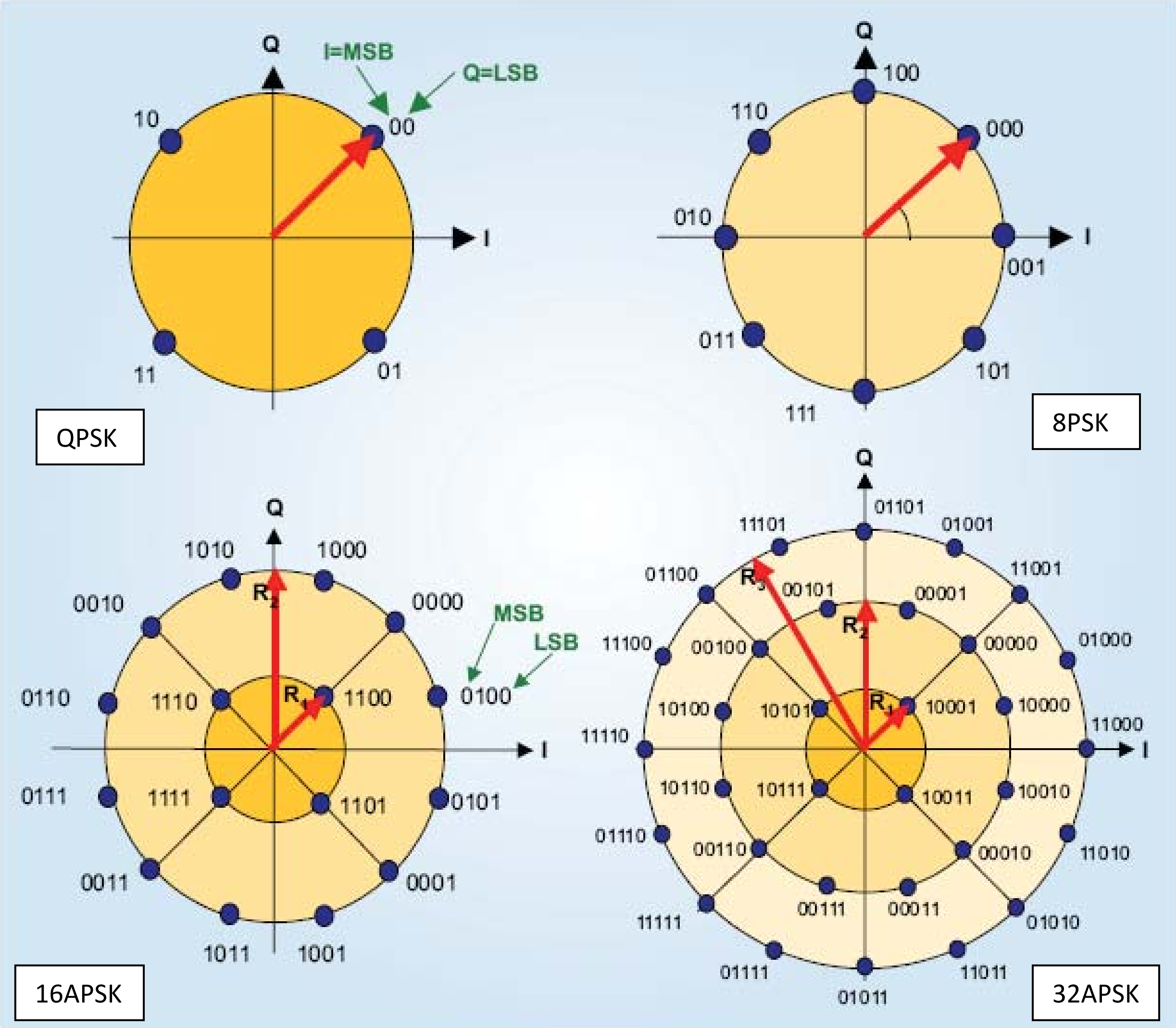
FEC and Modulation

The FEC is the key subsystem to achieve excellent performance by satellite, in the presence of high levels of noise and interference. The selection process, based on computer simulations, compared seven proposals – parallel or serially concatenated convolutional codes, product codes, low density parity check codes (LDPC) – all using “turbo” (i.e. recursive) decoding techniques. The winning system, based on LDPC, offered the minimum distance from the Shannon limit on the linear AWGN channel, under the constraint of maximum decoder complexity of 14 mm$^{\wedge 2}$ of silicon (0.13 µm technology).

The selected LDPC codes use very large block lengths (64800 bits for applications not too critical for delays, and 16200 bits). Code rates of 1/4, 1/3, 2/5, 1/2, 3/5, 2/3, 3/4, 4/5, 5/6, 8/9 and 9/10 are available, depending on the selected modulation and the system requirements. Coding rates 1/4, 1/3 and 2/5 have been introduced to operate, in combination with QPSK, under exceptionally poor link conditions, where the signal level is below the noise level. Concatenated BCH outer codes are introduced to avoid error floors at low bit error rates (BER).

Four modulation modes can be selected for the transmitted payload . QPSK and 8PSK are typically proposed for broadcast applications since they are virtually constant envelope modulations and can be used in non-linear satellite transponders driven near saturation. The 16APSK and 32APSK modes, mainly targeted at professional applications, can also be used for broadcasting, but these require a higher level of available C/N and the adoption of advanced pre-distortion methods in the up-link station to minimize the effect of transponder non-linearity.

Whilst these modes are not as power-efficient as the other modes, the spectrum efficiency is much greater. The 16APSK and 32APSK constellations have been optimized to operate over a non-linear transponder by placing the points on circles. Nevertheless their performance on a linear channel are comparable with those of 16QAM and 32QAM respectively.



By selecting the modulation constellation and code rates, spectrum efficiencies from 0.5 to 4.5 bit per symbol are available and can be chosen dependant on the capabilities and restrictions of the satellite transponder used.

DVB-S2 has three “roll-off factor” choices to determine spectrum shape: 0.35 as in DVB-S, 0.25 and 0.20 for tighter bandwidth restrictions.

DVB-S2 physical layer signal is composed of a regular sequence of “lorries” (frames): within a lorry, the modulation and coding scheme is homogeneous, but may change (Adaptive Coding & Modulation) in adjacent lorries. Every frame is composed of a payload of 64800 bits (or 16200 bits), corresponding to a code block of the concatenated LDPC/BCH FEC, and a Header (90 binary modulation symbols), containing synchronization and signalling information. Since the PL

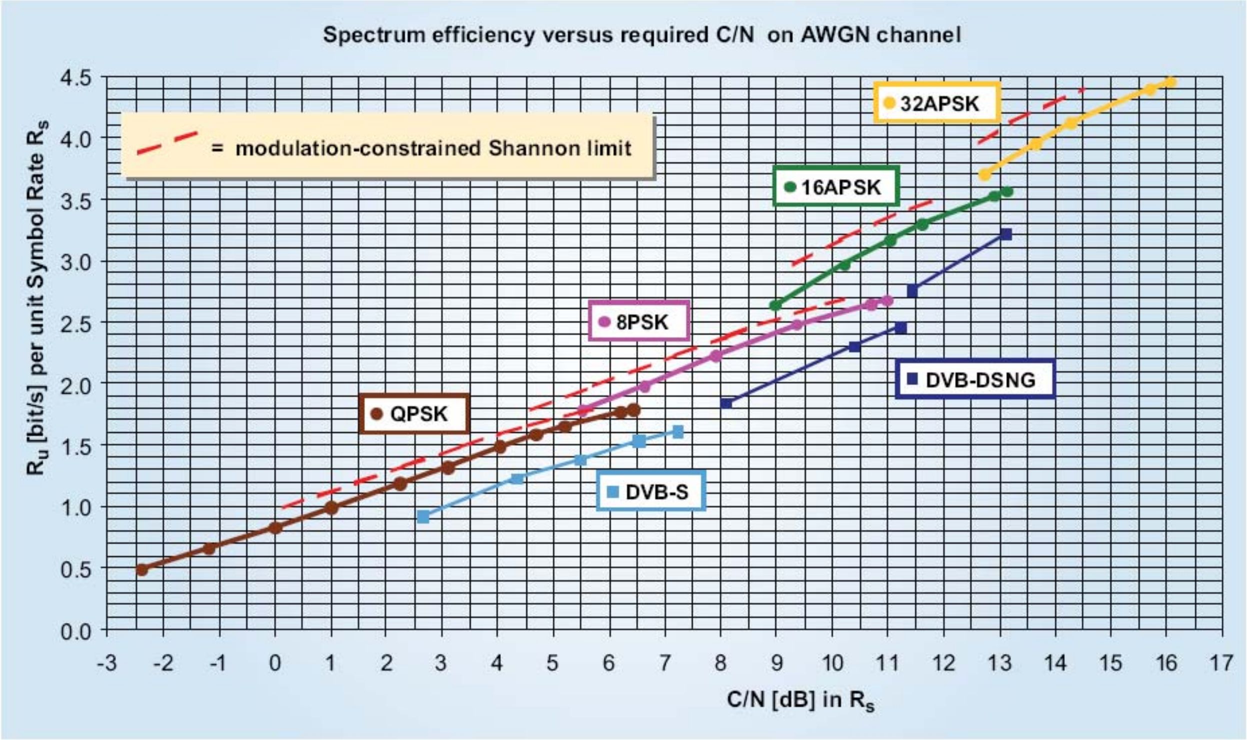
Header is the first entity to be decoded by the receiver, it could not be protected by the powerful LDPC/BCH FEC scheme.

On the other hand, it had to be perfectly decodable under the worst-case link conditions. Therefore the system designers selected a very low-rate 7/64 block code to protect it, suitable for soft-decision correlation decoding, and minimized the number of signaling bits to reduce decoding complexity and global efficiency loss.

The second level of framing structure, the "baseband frame", allows a more complete signaling functionality to configure the receiver according to the application scenarios: single or multiple input streams, generic or transport stream, CCM (Constant Coding & Modulation) or ACM (Adaptive Coding & Modulation), and many other configuration details. Thanks to the LDPC/BCH protection and the wide length of the FEC frame, the Baseband (BB) Header may contain many signalling bits (80) without losing transmission efficiency or ruggedness against noise.

System Performance

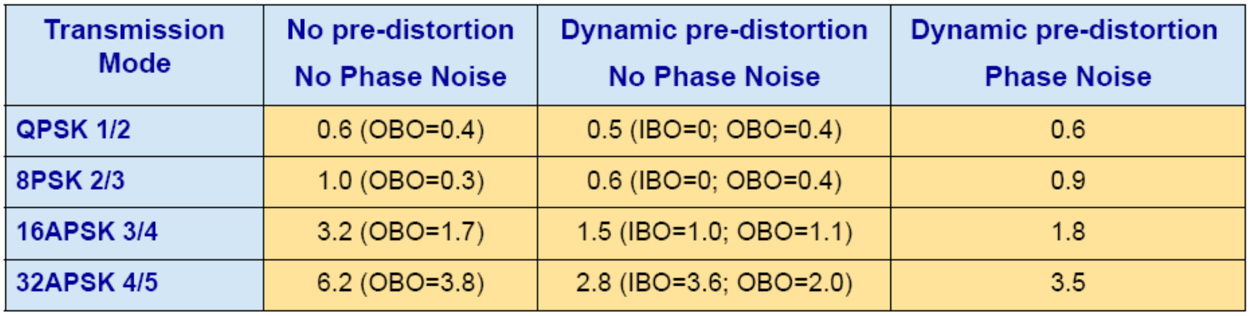
Dependant on the selected code rate and modulation constellation, the system can operate at carrier-to-noise ratios from –2.4 dB (using QPSK 1/4) to 16 dB (using 32APSK 9/10), assuming an AWGN channel and ideal demodulator (see Fig. 3). These results have been obtained by computer sion hour in a 5 Mbit/s video service). The distance from the Shannon limit ranges from 0.7 to 1.2 dB. On AWGN, the result is typically a 20 – 35 percent capacity increase over DVB-S and DVBDSNG under the same transmission conditions and 2 – 2.5 dB more robust reception for the same spectrum efficiency. The DVB-S2 system may be used in "single-carrier-per-transponder" or in "multi-carriers-per-transponder" (FDM) configurations. The figure also indicates examples of the useful bitrate capacity Ru achievable by the system in the different modulation/coding configurations, assuming unit symbol rate RS. The symbol rate RS corresponds to the –3dB bandwidth of the modulated signal, while RS(1+α) corresponds to the theoretical total signal bandwidth after the modulator, with α representing the roll-off factor of the modulation.



The use of the narrower roll-off α = 0.25 and α = 0.20 may allow a transmission capacity increase, but may also produce larger non-linear degradations by satellite for single-carrier operation. When DVB-S2 is transmitted by satellite, quasi-constant envelope modulations such as QPSK and 8PSK are power efficient in the single-carrier-per-transponder configuration, since they can operate on transponders driven near saturation. 16APSK and 32APSK, which are inherently more sensitive to non-linear distortions and would require quasi-linear transponders (i.e., with larger Output Back-Off, OBO) may be improved in terms of power efficiency by using non-linear compensation techniques in the up-link station . In FDM configurations, where multiple carriers occupy the same transponder, this latter must be kept in the quasi-linear operating region (i.e., with large OBO) to avoid excessive inter-modulation interference between signals. In this case, the AWGN performance figures may be adopted for link budget computations.

The following table shows, for the single-carrier-per-transponder configuration, the simulated C/N degradation using the satellite channel models and phase noise mask given in ETSI: EN 302 307(non-linearised TWTA, phase noise relevant to consumer LNBs), at the optimum operating TWTA point (computer simulations by

ESA). CSAT is the un-modulated carrier power at HPA saturation, OBO is the measured power ratio (dB) between the un-modulated carrier at saturation and the modulated carrier (after OMUX). The figures show the large advantage offered by the use of dynamic pre-distortion for 16APSK and 32APSK. The large phase noise degradations quoted for APSK, and in particular for 32APSK, can be considered as pessimistic, since they refer to consumer-type LNBs while, for professional applications, better front-ends may be adopted at negligible additional cost.



Transmission Mode	No pre-distortion No Phase Noise	Dynamic pre-distortion No Phase Noise	Dynamic pre-distortion Phase Noise
QPSK 1/2	0.6 (OBO=0.4)	0.5 (IBO=0; OBO=0.4)	0.6
8PSK 2/3	1.0 (OBO=0.3)	0.6 (IBO=0; OBO=0.4)	0.9
16APSK 3/4	3.2 (OBO=1.7)	1.5 (IBO=1.0; OBO=1.1)	1.8
32APSK 4/5	6.2 (OBO=3.8)	2.8 (IBO=3.6; OBO=2.0)	3.5

C sat / N loss in dB on the satellite channel

Adaptive Coding and Modulation

When DVB-S2 is used for interactive point-to-point applications like IP unicasting, its gain over DVB-S is even greater, if Adaptive Coding and Modulation (ACM) schemes are used. In fact ACM allows us to recover the so called “clear sky margin” (4 to 8 dB of power), typically wasted in conventional “constant coding and modulation” satellite links, thus doubling or even tripling the average satellite throughput and reducing dramatically the service cost . The ACM gain versus CCM increases for critical propagation conditions: therefore ACM is fundamental for the higher frequency bands (e.g. Ka band) and for tropical climatic zones. Fig. 4 shows the scheme of an ACM satellite link, composed of an ACM Gateway (GW), the DVB-S2 ACM modulator, the up-link station, the Satellite and the Satellite receiving Terminal (ST) connected to the ACM GW via a return channel. The DVB-S2 ACM modulator operates at constant symbol rate, since the available transponder bandwidth is assumed to be constant. ACM is implemented by the DVB-S2 modulator by transmitting a TDM sequence of frames, where coding and modulation format may change frame-by-frame. Therefore service continuity is achieved, during rain fades, by reducing user bits while increasing at the same time the FEC redundancy and/or modulation ruggedness.

Physical layer adaptation is achieved as follows:

1) Each ST measures the channel status (available C/N+I) and reports it via the return channel to the Gateway (GW);

2) The ST reports are taken into account by the GW while selecting the assigned protection level for data packets addressed to the ST;

3) In order to avoid information overflow during fades, a user bit rate control mechanism should in principle be implemented, adapting the offered traffic to the available channel capacity. This can be implemented in various ways, according to the specific service requirements and network architecture. The GW imposes error protection, applied to a given portion of user data via suitable interfacing mechanisms. With respect to one-to-one services (e.g., DSNG), IP unicast links using DVB-S2 ACM must adapt the error protection on a user-per-user basis: the number of users may be very large (e.g. up to hundreds of thousands). Furthermore, direct source rate control may be impossible, since information sources (IP information providers) are far from the satellite GW.

A crucial issue in ACM systems is the physical layer adaptation loop delay, as it is strictly linked to the system capability of tracking channel variations. If loop adaptation is fast, service continuity may be guaranteed even during fast rain fades while, at the same time, keeping low C/N transmission margins to maximize the overall system throughput. Since maximum C/N+I variation rates at Ka band have been estimated to be of about 0.5 dB per second during heavy rain fades [2], and since the C/N distance between two adjacent DVB-S2 protection levels is around 1 dB, control loop delays smaller than 1 second should allow minimization of transmission packet losses.

The following table shows the different spectral efficiencies for the different ModCods supported in DVB-S2

Modulation	bits/S	Code rate	Spectral Efficiency
QPSK	2	0.25	0.49024300
QPSK	2	0.33	0.65644800
QPSK	2	0.40	0.78941200
QPSK	2	0.50	0.98885800
QPSK	2	0.60	1.18830400
QPSK	2	0.67	1.32225300
QPSK	2	0.75	1.48747300
QPSK	2	0.80	1.58719600
QPSK	2	0.83	1.65466300
QPSK	2	0.89	1.76645100
QPSK	2	0.90	1.78861200
Modulation	**bits/S**	**Code rate**	**Spectral Efficiency**
8PSK	3	0.60	1.77999100
8PSK	3	0.67	1.98063600
8PSK	3	0.75	2.22812400
8PSK	3	0.83	2.47856200
8PSK	3	0.89	2.64601200
8PSK	3	0.90	2.67920700
Modulation	**bits/S**	**Code rate**	**Spectral Efficiency**
16APSK	4	0.67	2.63720100
16APSK	4	0.75	2.96672800
16APSK	4	0.80	3.16562300
16APSK	4	0.83	3.30018400
16APSK	4	0.89	3.52314300
16APSK	4	0.90	3.56734200
Modulation	**bits/S**	**Code rate**	**Spectral Efficiency**
32APSK	5	0.75	3.70329500
32APSK	5	0.80	3.95157100
32APSK	5	0.83	4.11954000
32APSK	5	0.89	4.39785400
32APSK	5	0.90	4.45302700

DVB-S2 Spectral Efficiency in bps/hz

Return Channel Satellite (RCS)

DVB-RCS is a technical standard, designed by the DVB Project, that defines a complete air interface specification for two-way satellite broadband VSAT (very small aperture terminal) systems. Low cost VSAT equipment can provide highly dynamic, demand-assigned transmission capacity to residential and commercial/institutional users. DVB-RCS provides users with the equivalent of an ADSL or cable Internet connection, without the need for local terrestrial infrastructure. Depending on satellite link budgets and other system design parameters, DVB-RCS implementations can dynamically provide anywhere up to 20 Mbit/s to each terminal on the outbound link, and up to 5 Mbit/s or more from each terminal on the inbound link. The standard is published by ETSI as EN 301 790.

DVB's Technical Module approved the DVB-RCS+M specification in 2008, providing support for mobile and nomadic terminals as well as enhanced support for direct terminal-to-terminal (mesh) connectivity. DVB-RCS+M includes features such as live handovers between satellite spot-beams, spread-spectrum features to meet regulatory constraints for mobile terminals, and continuous-carrier transmission for terminals with high traffic aggregation. It also includes link-layer forward error correction, used as a countermeasure against shadowing and blocking of the satellite link.

In its basic form, DVB-RCS provides "hub-spoke" connectivity; i.e., all user terminals are connected to a central hub that both controls the system and acts as a traffic gateway between the users and the wider Internet. The user terminal consists of a small indoor unit, and an outdoor unit with an antenna size not much bigger than a conventional direct-to-home TV receiver. Since the DVB-RCS terminal also transmits data the outdoor unit includes an RF power amplifier.

The user terminal offers an IP over Ethernet connection that can be used for wired or wireless interactive Internet connectivity for a local home or office network ranging from one to several users. In addition to providing interactive DVB services and IPTV, DVB-RCS systems can thus provide full IP connectivity anywhere there is suitable satellite coverage, which in turn means most places on earth including areas not covered by other solutions.

The core of DVB-RCS is a multi-frequency Time Division Multiple Access (MF-TDMA) transmission scheme for the return link, which provides high bandwidth efficiency for multiple users. The demand-assignment scheme uses several capacity mechanisms that allow optimization for different classes of applications, so that voice, video streaming, file transfers and web browsing can all be handled efficiently. DVB-RCS supports several access schemes making the system much more responsive, and thus more efficient, than traditional demand-assigned satellite systems. These access schemes are combined with a flexible transmission scheme that includes state-of-the-art turbo coding, several burst size options and efficient IP encapsulation options. These tools allow systems to be fine-tuned for the best use of the power and bandwidth satellite resources.

The forward link is shared among a population of terminals using either the highly efficient DVB-S2 standard (EN 302 307) or the widely deployed DVB-S (EN 300 421). Adaptive transmission to overcome variations in channel characteristics (e.g., rain fade) can be implemented in both the forward and return links. Beyond the basic hub-and-spoke architecture, the DVB-RCS air interface has also been deployed in systems that provide direct terminal-to-terminal “mesh” connectivity, either through satellite on-board processors that mirror the functions of a ground-based hub, or through transparent satellites, using terminals equipped with an additional demodulator.

DVB-S2 is not replacing DVB-S in the short term for conventional TV broadcasting applications. Millions of DVB-S decoders are already operating reliably and contributing to successful digital satellite businesses around the world. New applications are being envisaged for satellite environments such as the delivery of consumer HDTV and the delivery of IP-based services. Combining DVB-S2 and new video and audio coding schemes (e.g. H.264), some 20 – 25 SDTV or 5 – 6 HDTV programmes may be broadcast in a conventional 36 MHz transponder. ACM tool may offer very large benefits for one-to-one connections, such as fly-away small terminals for military applications and commercial mobile vessels. In these new application areas, DVB-S2 will do what DVB-S could never have done.