FRAUNHOFER INSTITUTE FOR INTEGRATED CIRCUITS IIS

DVB-S2X IMPLEMENTED

Technical Fast Facts

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DVB-S2X Implemented

Satellite communication is a multi-billion market, with dozens of satellites being launched each year, providing terabytes of capacity worldwide. Despite the growth of alternative and competing terrestrial and wireless solutions, satellite continues being a must-have for areas not or just barely connected and shows its full economic potential in supporting one-to-many connectivity.

DVB-S2 is the de-facto standard being used in direct-to-home (DTH) satellite TV distribution. DVB-S2 is also widely adopted in satellite broadband (»satellite internet«) for the user downlink and in many interactive or professional peer-to-peer networks. Compared to DVB-S2 developed and specified in the early 2000s, DVB-S2X is a state-of-the art, backwards-compatible extension and superset, providing higher spectral efficiencies and new features to enable or promote new applications.

Fraunhofer IIS was actively involved in the development, specification and validation of DVB-S2X. The subsequent section provides further insight into

- how DVB-S2X differs from and extends DVB-S2;
- key additional features in DVB-S2X and their implication on performance and for new applications; and
- DVB-S2X technology and IP available at Fraunhofer IIS for specific markets.

Focus is on providing a high-level overview on technology and markets to all interested in DVB-S2X.

Why Satellite Communication? Why DVB-S2X?

Satellite communication can be anything from a tiny communication link into the middle of nowhere to the backbone technology of direct-to-home (DTH) TV broadcast. Compared to competing technology, satellite communication has a unique advantage in several domains:

- **Alternative infrastructure is technically not feasible**. This includes applications like in-flight entertainment, in-flight internet connectivity or maritime services: It just isn't an option using cable, fiber or backhaul connected wireless technology in or over the middle of an ocean.
- **Alternative infrastructure is not deployed**. This includes scenarios where connectivity is urgently needed but conventional infrastructure has not yet reached the area – or where the connectivity need is temporal and too short to upgrade alternatives. This is specific for »on the move« scenarios, including, but not limited to the military domain (MILCOM). This also includes time-limited backhauling for mobile phone networks spreading out into rural areas or news and data gathering applications with instantaneous demand.
- **Satellite having the superior total cost of ownership**. Application examples include remote sites connectivity using dedicated satellite links and satellite broadband – providing internet access to end-user premises in rural or remote areas. In this case satellite per se may not be the cheapest or best technical option, but any alternative infrastructure is eliminated by prohibitive investment cost for each individual site.

- **One-to-many connectivity**. A single TV or radio broadcast satellite may easily provide content and data to 100 millions of users. Compared to competitive technologies that physically or wirelessly connect each individual user, satellite broadcast allows an unlimited number of users being reached with no per-user infrastructure cost penalty.

In brief, the improvements in DVB-S2X address the above opportunities as follows:

- **Improved performance and spectral efficiency**, squeezing more sellable capacity out of the same amount of spectrum, or, vice versa, providing lower cost per bit.
- **Additional features**, allowing more robust communication and enabling new applications and use cases.

In this context, DVB-S2X should be seen as a tool-box, with certain tools addressing certain challenges and opportunities and where each implementer is free to pick the subset that is believed to be best suited for an application or market, but also to differentiate a DVB-S2X product from the competition.

Implementation Details

DVB-S2X is an extension of the DVB-S2 specification; therefore DVB-S2X has been published as ETSI EN 302 307 part 2, with DVB-S2 being ETSI EN 302 307 part 1. Any DVB-S2X receiver is backwards compatible with DVB-S2 as the »part 1« capabilities are mandatory. Legacy DVB-S2 (only) receivers are not required being forward compatible, thus legacy DVB-S2 receivers will not decode transmissions using new DVB-S2X features.

Some features are transparent to DVB-S2 receivers, thus DTH transmissions may be constructed to be usable for both DVB-S2 and DVB-S2X receivers, with only the latter making use of the additional capabilities. On the long run, once DVB-S2X DTH receivers have reached sufficient market penetration, broadcasters are expected to pool attractive content in DVB-S2X-only channels, cutting down the legacy DVB-S2 offer – similar to the transformation from DVB-S to DVB-S2 at the beginning of the high-definition TV era.

A plurality of the technical improvements in DVB-S2X is focused on improving performance and spectral efficiency, both in the Physical Layer (PHY) and on System Level:

- **Increased granularity in modulation and coding (MODCODs).** Compared to the coarse MODCODs in DVB-S2 that provided roughly a 1 dB granularity in decoding threshold, DVB-S2X MODCODs are typically only 0.3 to 0.5 dB apart. On average, this allows selecting a MODCOD that more precisely fits the link characteristics, reducing unnecessary margins in DTH and broadband applications. Over the range from 5 dB to 15 dB, this results in an average capacity gain in the range of 4%.

- **Pulse shaping using sharper roll-off filters.** DVB-S2 supports roll-off ratios from 35% down to 20%, while DVB-S2X supports roll-off ratios down to 5%. At 20% roll-off, DVB-S2 effectively uses ${}^{1}/_{1.20} = 83.3\%$ of the assigned spectrum; compared to this, DVB-S2X may utilize up to ${}^{1}/_{1.05} = 95.2\%$ of the assigned spectrum, resulting in close to 15% gain in capacity. However, on power-limited transponders approx. one half of this capacity gain cannot be realized due to receiver signal power being reduced by $10 \cdot \log_{10}\left({}^{1.05}/_{1.20}\right) = -0.58\ dB$, resulting in an effective capacity gain of around 7% for DTH and broadband applications.

- **Higher modulation schemes up to 256APSK.** The DVB-S2 MODCOD range ends at 32APSK 9/10, providing a spectral efficiency of 4.5 Bit/Hz for a decoding threshold of 16.05 dB. DVB-S2X extends the MODCOD range up to 256APSK 3/4, providing 6.0 Bit/Hz for a decoding threshold of 19.57 dB. This extended range may be exploited by broadband applications on modern high-throughput satellites (HTS) – exceeding the 16.05 dB DVB-S2 limit under clear sky conditions – and for professional equipment using larger ground antennas on conventional satellites.
- **MODCODs optimized for linear transponder.** DVB-S2X adds a complementary set of MODCODs (indicated by a »-L« suffix) for use on quasi-linear channels subject to phase noise. These additional MODCODs lower the decoding threshold by up to 1 dB for the same spectral efficiency. A typical use case includes satellite transponders operated in multi-carrier mode with appropriate back-off; examples include the return link in broadband systems and applications leasing spectrum for rather narrowband carriers used in remote-site or backhaul connectivity.
- **Support for ultra-wideband carrier.** Use of single wideband carriers occupying the full traveling-wave tube amplifier (TWTA) bandwidth results in vastly improved inter-modulation performance. C/I_{IM} improves from around 20 dB for a multi-carrier signal on a linearized TWTA to above 25 dB for a single carrier signal on the same TWTA, having a noticeable effect on the end-to-end link budget. To support the efficient decoding of such wideband carriers in consumer-grade receivers, DVB-S2X introduces a time-slicing mechanism that requires the receiver to only process short time burst of »useful« information and allows using the time in between such bursts for processing. This system-level feature is predominantly designed for DTH and broadband applications – use cases that require enough throughput to fill an entire transponder (e.g. 500 MHz) with data.
- **Channel bonding.** As bandwidth on a transponder is sliced into carriers, some of the available transponder bandwidth may remain unused – as the remaining bandwidth is too little or too fragmented for reasonably sized carrier. DVB-S2X provides additional signaling for »bonding« such left-over capacity from up to 3 transponders into one transport stream. This system-level feature is especially beneficial for DTH on conventional 36 MHz-type transponders, providing bonded bandwidth for an extra transport stream, sufficiently large for high-definition and ultra-high-definition content.
- **Co-channel interference mitigation**. Configurable scrambling sequences increased resilience to co-channel interference caused by other satellites or other beams on the same satellite. This feature became mandatory in DVB-S2X also for DTH receivers and may optimally be extended to apply time-aligned super-frame wide scrambling for improved pilot recovery. The latter is especially beneficial for HTS satellites used for broadband applications.
- **Multiplexing gain.** Both ultra-wideband carrier and channel bonding extend the capacity pool available for statistical multiplexing, smoothing the statistical spread (or peak-to-average) in instantaneously required capacity. This reduces the safety margin required for peak temporal capacity demand and results in more use- and sellable capacity.

Besides performance improvements, DVB-S2X also adds a number of physical layer and system level features for new use cases or for improving the robustness in existing applications.

- **Support for very low signal-to-noise ratio (VL-SNR) operation.** DVB-S2X extends the operational range down to SNR levels as low as -10 dB by providing an additional set of MODCODs with low modulation and high redundancy plus additional »mobile frame sync« fields to support synchronization under such low SNR conditions. Low SNR frames (aka »mobile frames«) may be interleaved with normal frames; backwards-compatible signaling allows normal receivers to ignore such a VL-SNR frame. VL-SNR operation is typically used for mobile reception (with small gain or potentially less accurately pointed antennas), but may also be used for improved drop-out resilience under deep-fade conditions.
- **Super-Framing.** Annex E of the DVB-S2X standard defines a super-frame structure, using constant length super-frames comprising of 612540 symbols, with 720 symbols (0.12%) being reserved for super-frame synchronization and format identification. The currently defined super-frame »profiles« support
  - robust VL-SNR operation, adding an additional VL-SNR header and a pilot field;
  - improved channel capacity and more aggressive frequency-reuse enabled by advanced interference mitigation at the receiver and/or precoding at the gateway.

Deciding on the supported feature set

Implementing the DVB-S2X standard may be complicated by the variety of different target applications and services and the richness in features – normative, optional or not applicable, depending on target application and service. Implementing DVB-S2X is further complicated by the wide throughput range a receiver may have to cover – less than 100 Mbps on a traditional satellite using 36 MHz transponder to in excess of 2000 Mbps on a 500 MHz transponder operated under high SNR conditions. Moreover the required receiver resources grow more than linear with carrier bandwidth and throughput.

Therefore, a receiver manufacturer not only has to decide on the supported feature set to be implemented and tested, but also on the trade-off between throughput, complexity and price of the silicon and implementation loss, e.g. resulting from efficient but limited accurate symbol demapping or from limiting the number of iterations in the LDPC decoding process. Clearly there is no one-size-fits-all solution, and a highly cost sensitive DTH receiver will be quite different from a professional high-end and high-throughput MODEM.

DVB-S2X: Be smart, get it right and get it done

Thorough understanding of DVB-S2X technology, the market needs and the constraints of the target application is vital for the right selection of the features and for building a unique and successful product. Thus, as an equipment or chipset manufacturer, benefit from Fraunhofer IIS' background and know-how when evaluating DVB-S2X as an extension to your product portfolio and when drafting the product's DVB-S2X features and capabilities in detail.

Implementing DVB-S2X easily consumes person-years of effort, not even counting functional validation and fine tuning the decoder performance. Adoption of a validated and field tested implementation minimizes technical and schedule risks. Contact us for an evaluation of a field tested FPGA receiver implementation and to discuss customizations and porting to alternative platforms and technologies.

Time-to-market is essential staying ahead of competition and for timely return of investment. Fraunhofer IIS offers a readily available DVB-S2X receiver implementation using Annex E, format 4 (super-framing) that can be quickly tailored for different products and throughput ranges. Different licensing options are available on request.