VersaFEC-2 Technology Description

Introduction to VersaFEC-2

Comtech EF Data designed and released the first generation VersaFEC system in the spring of 2007 in the CDM-625 Advanced Satellite Modem. This initial waveform was specified and designed to provide high performance, low latency Constant Coding and Modulation (CCM) and Adaptive Coding and Modulation (ACM) operation based on LDPC encoding/decoding for sub 5Msps channels. This first generation ("VersaFEC") achieved immediate industry acceptance, becoming the "go-to" solution for low to medium rate data links that required the spectral performance of the waveform with low-latency operation. VersaFEC is currently incorporated into three Comtech EF Data products (product families), the CDM-625 / CDM-625A / CDMER-625A modems, the CDM-570A / CDM-570AL modems and the Advanced VSAT platform.

While the performance levels of VersaFEC set the high-bar mark for efficiency for low to medium rate channels, the industry required even stronger performance and better resulting economics. Because of this, Comtech EF Data designed the VersaFEC-2 waveform, and is incorporating this new innovation into its product suite to allow mobile network operators and service providers to continue to control costs while providing the ever-increasing service levels that end users demand. It is the purpose of this paper to describe this next generation, extensible VersaFEC-2 Waveform System (VWS) design, compare it to the DVB-S2 and DVB-S2x standards along with its predecessor, VersaFEC, and highlight the advantages seen when utilizing the new innovation.

VersaFEC-2 High-Performance LDPC release for CDM-625A

The high-performance VersaFEC-2 waveform has been designed form the ground up to provide optimal performance for applications from 100 ksps to 12.5 Msps. The VersaFEC-2 waveform is comprised of 74 new ModCods with a new family of constellations. Similar to the DVB-S2 and DVB-S2x industry standards, VersaFEC-2 provides two (2) operational modes, Long-Block and Short-Block. Long-Block provides 38 ModCods with coding gain and spectral efficiencies better than DVB-S2 and on par with DVB-S2x at approximately 1/8 the data latency of these two standards. VersaFEC-2 Short-Block provides 36 ModCods with better performance than the industry proven VersaFEC at similar or better data latencies. All higher order constellations within VersaFEC-2 are quasi-circular for optimal peak-to-average performance, which makes them less prone to performance degradation in non-linear satellite channels. In addition, new 32-ary modulation has been added to support spectral efficiencies up to 4.4 bps/Hz. Both CCM and ACM operation are supported in both Long-Block and Short-Block modes. Comtech EF Data is releasing the first of multiple components of the VWS into the CDM-625A modem in October of 2014.

VersaFEC-2 High Performance LDPC vs. DVB-S2

The VersaFEC-2 high-performance waveform provides significant performance advantage over industry standard DVB-S2 as well as its predecessor, VersaFEC. Figure 1 compares the Long Block version of VersaFEC-2 with Long Block DVB-S2.

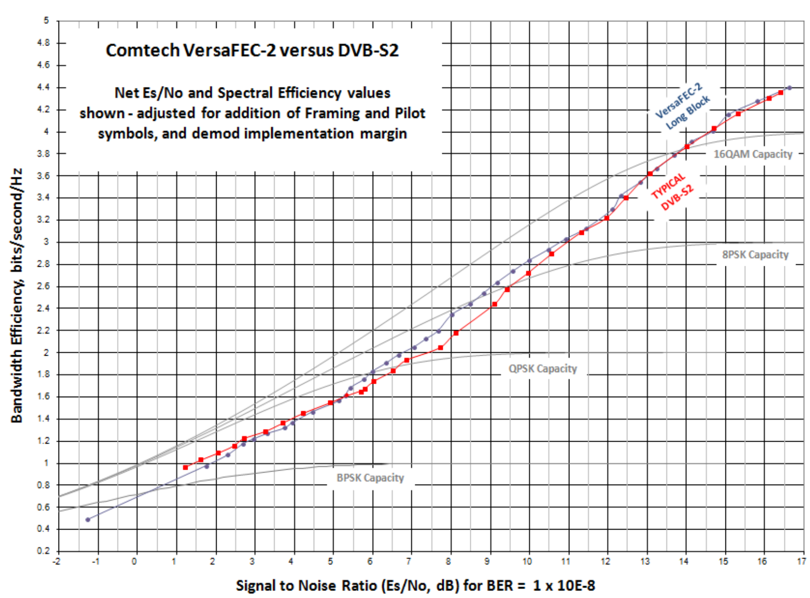

Figure 1: VersaFEC-2 vs. DVB-S2

As depicted in Figure 1, VersaFEC-2's spectral efficiency is higher than the DVB-S2 standard in the scenarios most common (5 dB to 11 dB terminal C/N) with low to medium range data rates applications, and is on par with the DVB-S2 standard at higher terminal C/N conditions. The increased performance levels of VersaFEC-2 directly affect the bottom line due to the fact that either:

- Additional throughput (Mbps) can be transmitted through a given satellite resource (MHz), resulting in an increase in revenue stream with a given OPEX cost structure, or
- Less satellite resource (MHz) would be required for a given throughput (Mbps), resulting in a decrease in OPEX cost structure for a given revenue stream.

In both cases, the mobile network operator or service provider sees significant benefits. For existing services, an increase in performance for the most common modes of operation directly correlates to an increase in margins, assuming end user pricing remains the same. Conversely, the modified economic model that results from a decreased cost basis opens the mobile network operator or service provider up to penetrate new markets. Or, combining the two, an enhanced level of services can be provided to end users. In all three cases, the use of Versa-FEC2 provides a mobile network operator or service provider the opportunity to grow their business through a differentiated level of service.

VersaFEC-2 vs. VersaFEC

Figure 2 provides a comparison of VersaFEC-2 with its predecessor, VersaFEC. As depicted in the figure, Versa-FEC2 provides up to a 1.7 dB improvement over VersaFEC.

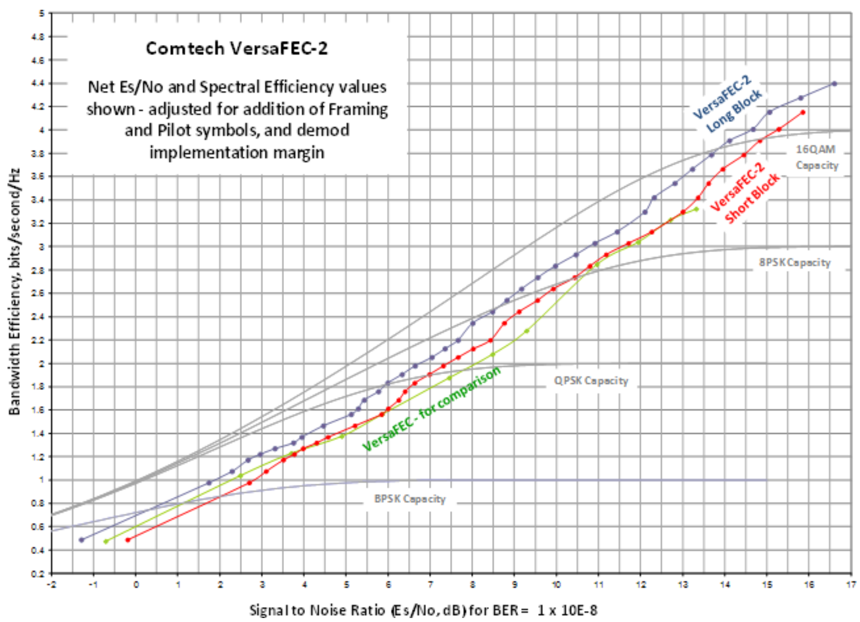

Figure 2: VersaFEC-2 vs. VersaFEC

Focus on Latency

It is Comtech EF Data's belief that a coding method that utilizes a constant number of symbols per block is superior to one that uses a constant bit per block model, as is done with the DVB standards, and designed this mechanism into VersaFEC with excellent results in terms of transmission latency. Likewise, VersaFEC-2, utilizing a constant symbol per block architecture, significantly outperforms DVB-S2 and DVB-S2x in latency performance. To highlight this difference, Table 1 provides a comparison of VersaFEC-2 performance against DVB-S2 or DVB-S2x in terms of channel latency for a 512 kbps link.

Waveform	ModCod	Data Rate	End-to-end latency (no Satellite)	VersaFEC-2 Advantage
DVB-S2 or DVB-S2x	QPSK Rate 0.5 Long Block	512 kbps	275 milliseconds	85% lower latency compared to equivalent DVB-S2
VersaFEC-2	QPSK Rate 0.489 Long Block	512 kbps	41 milliseconds	
DVB-S2 or DVB-S2x	QPSK Rate 0.5 Short Block	512 kbps	72 milliseconds	91% lower latency compared to equivalent DVB-S2
VersaFEC-2	QPSK Rate 0.489 Short Block	512 kbps	7 milliseconds	

Table 1: End-to-End Processing Latency of VersaFEC-2 vs. DVB-S2/DVB-S2x

As can be seen from Table 1, whether the Long Block or Short Block option is utilized, the end-to-end latency of the VersaFEC-2 options is a small fraction of those associated with the DVB standards. This added latency significantly affects all connection-oriented or interactive applications, either severely reducing the speed and quality of the application or, worse, causing the application not to operate at all.

The VersaFEC coding mechanisms were designed from the ground up with the requirements of the underlying applications in mind. For mobile network operators, it is extremely important to ensure the underlying signaling protocols for 2G, 3G and 4G are able to function correctly… and quickly. Latency and jitter tolerances of these protocols are very low and it's important to select a transmission mechanism that can allow these systems to operate properly. For enterprise uses, Citrix and similar business applications are extremely sensitive to high latency. Connections that insert a high level of latency can cause unnecessary retransmissions, strain on the network and, at times, connection terminations. When these occurrences are high, unsatisfactory user experiences arise, decreasing productivity and creating negative impacts to the bottom line.

Focus on Carrier Acquisition Times

Similar to the advantages highlighted above, a constant symbol per block approach provides significant advantages in carrier acquisition performance. Table 2 summarizes typical carrier acquisition times of a DVB-S2 or DVB-S2x carrier versus a VersaFEC-2 carrier at 1Msps.

Waveform	ModCod	Symbol Rate	Typical Carrier Acquisition
DVB-S2 or DVB-S2x	QPSK Rate 0.5 Long Block	1 Msps	>2 seconds
VersaFEC-2	QPSK Rate 0.489 Long Block	1 Msps	< 60 msec
DVB-S2 or DVB-S2x	QPSK Rate 0.5 Short Block	1 Msps	>2 seconds
VersaFEC-2	QPSK Rate 0.489 Short Block	1 Msps	< 60 msec

Table 2: Typical Carrier Acquisition of VersaFEC-2 vs. DVB-S2/DVB-S2x

Carrier acquisition time is important when channels dynamically de-tune and re-tune, as is the case with dynamic SCPC (dSCPC) operation. With dSCPC operation, carriers are dynamically resized to support changes in traffic demand throughout a network. As with VersaFEC, the new design ensures that switching times are minimized and do not degrade connections that have strict latency and jitter requirements. Lowest possible acquisition time is key to the operation of Advanced VSAT solutions.

Focus on Adaptive Coding & Modulation (ACM)

Adaptive Coding and Modulation (ACM) is a transmission technique in which the modulation and FEC are modified on the fly to accommodate satellite link degradation. When a degradation occurs, the chosen modulation and coding are "ramped down" to allow the link to be received at the proper level at the remote end to ensure connectivity. At the remote end, an ACM demodulator measures the receive signal power and uses that to determine if a change in modulation and FEC is warranted. When the receive signal C/N or Es/No changes, the modulation and coding would change again to meet the service level requirements. If receive levels rise, the modulation and coding would "ramp up" to a more aggressive (and more spectrally efficient) combination. On the other hand, if further degradation occurs, modulation and coding would continue to decrease (along with spectral efficiencies) until proper receive levels are reached to ensure connectivity.

If an ACM mechanism is not selected, as is the case with Constant Coding and Modulation (CCM), a link must be designed for the worst case condition to ensure proper connectivity. In other words, the modulation and coding that would ensure operation under the most adverse conditions must be chosen and this combination would need to be used at all times. This is a huge detriment to the CCM method and a large waste of OPEX as adverse environmental conditions, while geographically dependent, are infrequent and for the vast majority of time, excess bandwidth is being procured that is not needed to close the link. Those that leverage ACM can take two routes:

- Additional throughput (Mbps) can be transmitted through a given satellite resource (MHz) a significant portion of the time since worse-case conditions occur very infrequently. This could result in an increase in revenue stream and/or enhanced service levels with a given OPEX cost structure, or
- Less satellite resource (MHz) would be required for a given contracted throughput (Mbps) as operation within the worst case environment (least aggressive mouldation and coding) would be minimized to a small fraction of time. The link can be designed to operate near a clear sky condition in steady state with still enough flexibility to meet a degraded sky condition, resulting in a decrease in OPEX cost structure for a given revenue stream.

VersaFEC-2 is designed inherently to support far-end demodulator metrics reporting so NO additional overhead is required to support ACM, which is key to maximize link efficiencies.

Conclusion

The Comtech EF Data product suite offers multi-dimensional optimization tailored towards user applications. This multi-dimensional optimization utilizes a building block approach, with the foundational block focused on providing the most robust and efficient modulation and coding possible. VersaFEC-2 is a high-performance, low-latency modulation and coding method that allows those that leverage it the many benefits of ACM operation. Building on the proven track record of its predecessor, VersaFEC, VersaFEC-2 adds a number of new modulation and coding methods, innovative new constellations and new operational modes that allow it to best support cellular backhaul and IP trunking solutions. Similar to its predecessor, VersaFEC-2 can be utilized in both directions of a link and can be combined with DoubleTalk Carrier-in-Carrier bandwidth compression in the CDM-625A Advanced Satellite Modem to achieve unprecedented spectral efficiencies.

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