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Methods to Increase Throughput for Point-to-Point Links

A financial & technical analysis comparing conventional point-to-point satellite circuits with circuits that employ Adaptive Coding and Modulation (ACM),DoubleTalk® Carrier-in-Carrier® technology (CnC), and combinations of ACM and CnC.

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Abstract

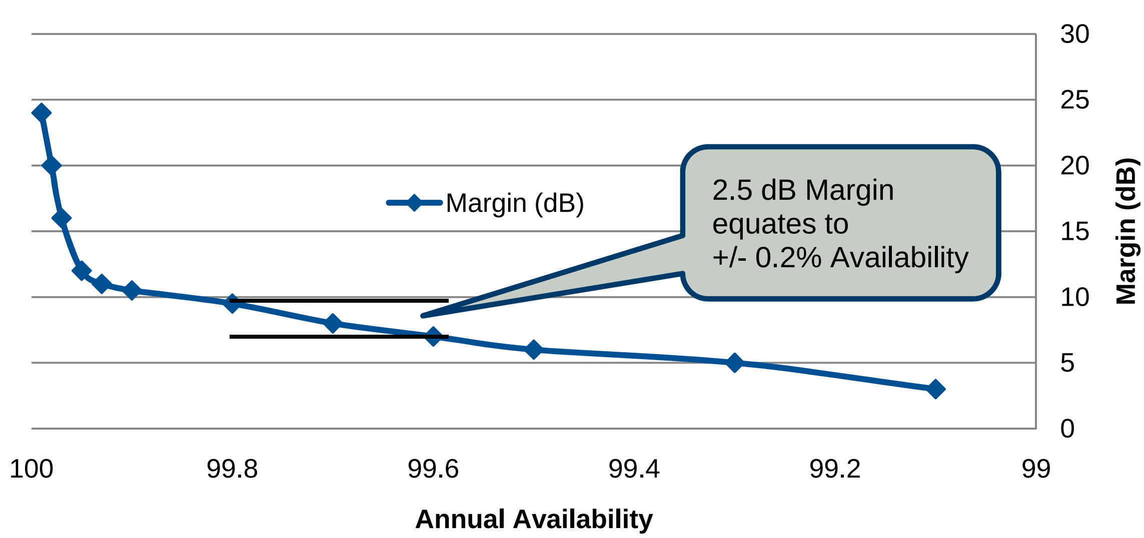
Today's service providers and satellite operators are under substantial pressure to maximize profits and minimize costs while providing customers improved reliability and higher capacity services. In the race to compete with industry peers, wireless services and terrestrial capacity, service providers and operators must constantly look to improve bandwidth utilization and user throughput to stay ahead. Advances in modulation, coding gain, fade adaptation and carrier cancelling technologies can provide substantial savings in bandwidth, improved capacity, improved reliability, or all three, while maintaining contracted service level agreements (SLAs). This paper summarizes the technical and financial benefits of these technologies independently and in combination for several real world scenarios.

Introduction to Adaptive Coding and Modulation (ACM)

Adaptive Coding and Modulation is a statistical, non-static advantage that enables dynamic changes in user throughput. Benefits and value vary over time and are not guaranteed, but are predictable. ACM technology converts link margin to an increase in the data throughput of satellite links. Only non-synchronous data networks (such as Ethernet packet-based networks) can take advantage of a dynamic data throughput rate. All satellite links are designed to function at a certain annual availability. The closer to 100% we demand of our link availability, the more link margin we need to meet this demand. Figure 1 below is a graph of availability vs. link margin of a Ku-Band link from Germany to Nigeria. A change in guaranteed annual availability from 99.8% to 99.6% (as little as 0.2% per year) equates to 17.5 hours per year (365 Day * 24hours/day * .002 = 17.5 Hours).

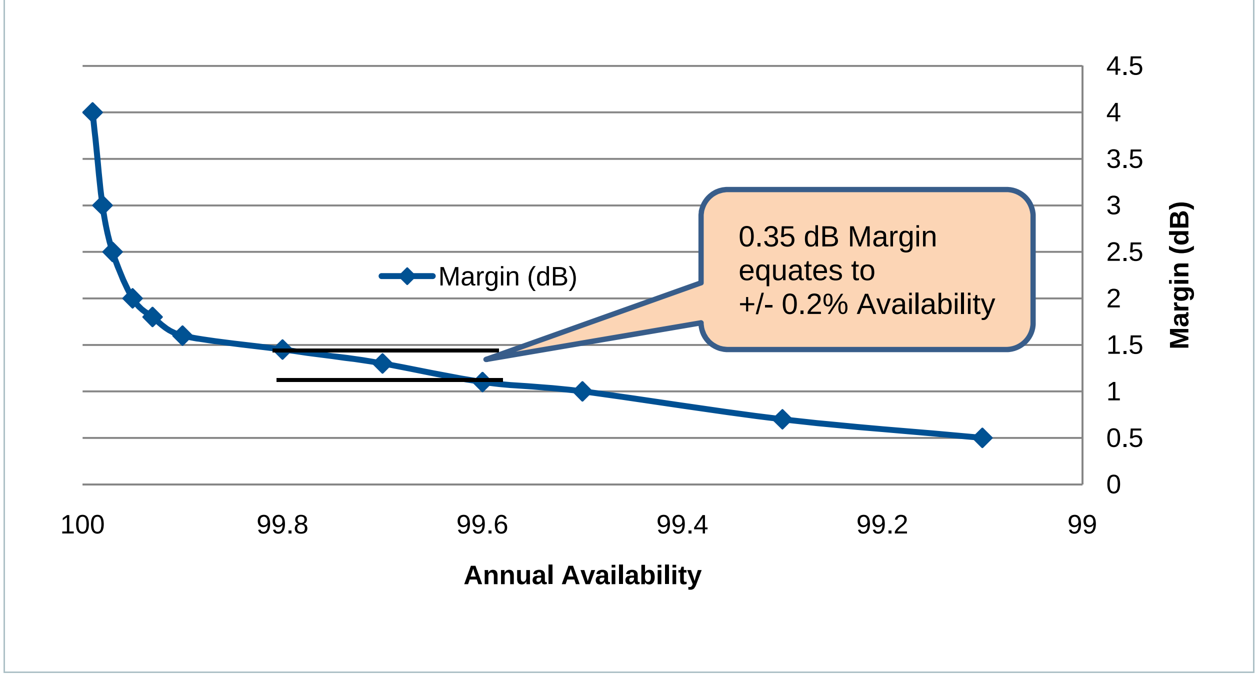
In this link, it can be seen that these 17.5 hours/year demands or saves 2.5 dB of link margin. This means that someone who requires 99.8% availability instead of 99.6% availability would need to factor and additional 2.5 dB of link margin for the entire year. Conversely, deciding to run this link with 99.6% availability would save 2.5 dB of link margin for the entire year.

Figure 1: Ku-Band Link Margin (dB)



Different links have different link margin requirements. Consider a C-Band link between Italy and China with very different link availability characteristics. In Figure 2 below you can clearly see that the same change from 99.6% availability to 99.8% availability requires a mere 0.35 dB of additional link margin.

Figure 2: C-Band Link Margin (dB)



Rain fade, inclined orbit satellite operation, antenna pointing errors, noise and interference can all degrade satellite link conditions. All of these conditions determine the overall link margin of a system. Because ACM converts link margin to additional user throughput, it can be clearly seen that the greater the link margin, the greater the benefit of ACM. As link margin is reduced, so too is the value of ACM. It can also be stated that as guaranteed availability is increased, link margin will also need to be increased. Conversely, as availability requirements are reduced, link margin will also be reduced and the value of ACM will therefore be reduced.

Introduction to Double Talk Carrier in Carrier

Unlike ACM, DoubleTalk Carrier-in-Carrier technology is a calculable, definitive and static advantage. Carrier-in-Carrier is based on Applied Signal Technology's DoubleTalk bandwidth compression technology. DoubleTalk uses "Adaptive Cancellation," a patented technology that allows the transmit and receive carriers of a full-duplex satellite link to be transmitted in the same transponder space. When combined with advanced forward error correction and modulation techniques, DoubleTalk Carrier-in-Carrier can deliver unprecedented operating expense savings. In addition to operating expense (OPEX) savings, DoubleTalk Carrier-in-Carrier can also provide capital expenditure (CAPEX) savings by allowing a smaller BUC/HPA and/or antenna.

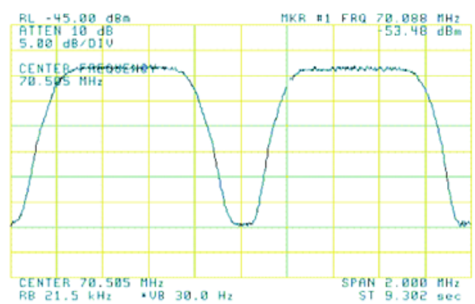


Figure 3: Conventional Full-Duplex Satellite Link

Figure 3 shows a conventional full-duplex satellite link, where two carriers are adjacent to each other and centered and different frequencies. Figure 4 shows the typical DoubleTalk Carrier-in-Carrier operation, where the two carriers are centered at the same frequency, thus sharing the same spectrum. When observed over a spectrum analyzer, only the Composite is visible. Carrier 1 and Carrier 2 are shown in Figure 4 for reference only.

DoubleTalk Carrier-in-Carrier is complementary to all advances in modem technology, including advanced FEC and modulation techniques. As these technologies approach theoretical limits of power and bandwidth efficiencies, DoubleTalk Carrier-in-Carrier (utilizing advanced signal processing techniques) provides a new dimension in bandwidth efficiency. DoubleTalk Carrier-in-Carrier allows satellite users to achieve spectral efficiencies (i.e. bps/Hz) that cannot be achieved with traditional links.

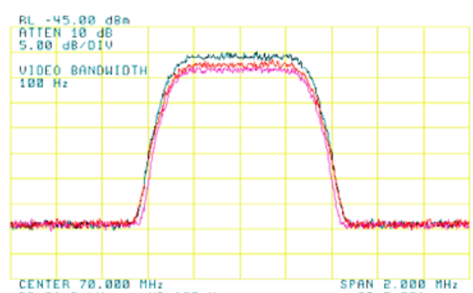


Figure 4: Duplex Link with DoubleTalk Carrier-in-Carrier

For example, DoubleTalk Carrier-in-Carrier when used with 16-QAM approaches the bandwidth efficiency of 256-QAM (8 bps/Hz).

As DoubleTalk Carrier-in-Carrier allows equivalent spectral efficiency using a lower order modulation and/or FEC code, it can simultaneously reduce CAPEX by allowing a smaller BUC/HPA and/or antenna. DoubleTalk Carrier-in-Carrier can be used to save transponder bandwidth and/or transponder power, thereby allowing successful deployment in bandwidth-limited as well as power-limited scenarios.

Case Studies

Using the highly regarded Intelsat Lease Transmission Plan Program (LST) link budget tool and actual Intelsat satellites, we have run four (4) satellite link budget scenarios. For the purpose of this exercise, all links in scenarios 1-3 require a duplex guaranteed minimum 10 Mbps data rate. All calculations are made using only DVB-S2 modulation and coding combinations to ensure there is no confusion between link budget operational points and inferior coding techniques. All BW figures use a transmit filter figure of 0.27 to calculate occupied BW (= SR * 1.27). Scenario 4 is a special case study specific to E3 link optimization.

Note that in all below scenarios, link margin remains consistent <u>within each scenario</u>. Link margin is directly related to link availability and therefore it follows that link margin remains consistent when doing a true comparison of technologies, weather you are running a conventional link, conventional link with ACM, Carrier-in-Carrier or Carrier-in-Carrier with ACM.

Definitions

[1] Occupied BW: This is the bandwidth that the carrier(s) actually occupy on the satellite. For conventional links, the occupied BW is equal to the Symbol Rate of the carrier times one plus the filter figure (Occupied BW = 1.27 * SR). In CnC links, when the carriers have equal symbol rates, we show the Occupied BW as (x.xx/2) because two carriers are using the same physical BW. Note, regardless of rolloff or filter figures used, all comparisons will equally benefit or suffer by the same percentage. This is a true comparison of technologies, not a misleading comparison using dissimilar criteria.

[2] Threshold Mod/Cod: In conventional links, this is the most spectrally efficient Mod/Cod with a QEF performance Es/No that is at or BELOW the Threshold Es/No for the link. In CnC carriers, the Threshold Mod/Cod must be the most spectrally efficient Mod/Cod with a QEF performance Es/No + CnC Es/No Penalty that is at or BELOW the Threshold Es/No for the link.

[3] CnC Es/No Penalty: This is the undesired penalty that must be added to the Threshold Es/No to determine the Threshold Mod/Cod that can be used when running CnC link budgets.

[4] Threshold Es/No Req: This is the worst case Es/No (most faded condition) the link will experience to accommodate the availability of the link. The Threshold Es/No will be negatively impacted (lower) when Link Availability is increased 99.8% -> 99.9% and will be higher when Link Availability is decreased 99.9% -> 99.8%.

[5] Clear Sky Es/No: This is the best Es/No value (least faded condition) the link will ever experience with the given satellite, earth station equipment, weather conditions etc.

[6] Link Margin: This is the difference between the Clear Sky Es/No and the Threshold Es/No. This is essentially the maximum delta in dB between best and worst case fade conditions.

[7] Total Allocated BW: In conventional links this is the sum of the Occupied BW of Link A to B and Link B to A. In CnC links, this is the larger of the two carriers, or if the carriers are the same size it is the sum of the Occupied BW of Link A to B divided by 2. A satellite operator will charge for the larger of either Total Allocated BW or Total PEB.

[8] Total PEB BW: Total Power Equivalent Bandwidth (PEB) relates to the amount of total power used by the carriers represented as a bandwidth equivalent. A satellite operator will charge for the larger of either Total Allocated BW or Total PEB.

[9] Clear Sky Mod/Cod A to B: In conventional links, this is the most spectrally efficient Mod/Cod with a QEF performance Es/No that is at or below the Clear Sky Es/No for the link A to B. In CnC carriers, it is the most spectrally efficient Mod/Cod with a QEF performance Es/No + CnC Es/No Penalty that is at or below the Clear Sky Es/No for the link A to B.
[10] ACM Max DR A to B: This is the maximum data rate achievable in clear sky conditions. This is calculated by multiplying the Clear Sky Mod/Cod A to B spectral efficiency with link A to B symbol rate or: Clear Sky Mod/Cod A to B spectral efficiency with (link A to B Occupied BW / 1.27).

[11] Clear Sky Mod/Cod B to A: In conventional links, this is the most spectrally efficient Mod/Cod with a QEF performance Es/No that is at or below the Clear Sky Es/No for the link B to A. In CnC carriers, it is the most spectrally efficient Mod/Cod with a QEF performance Es/No + CnC Es/No Penalty that is at or below the Clear Sky Es/No for the link B to A.

[12] ACM Max DR B to A: This is the maximum data rate achievable in clear sky conditions. This is calculated by multiplying the Clear Sky Mod/Cod B to A spectral efficiency with link B to A symbol rate or: Clear Sky Mod/Cod A to B spectral efficiency with (link A to B Occupied BW / 1.27)

[13] Total DR Increase %: This is the difference between the minimum guaranteed DR (10 Mbps *2 = 20 Mbps) and the sum of ACM Max DR A to B and ACM Max DR B to A as a percentage.

[14] Summary Section: BW/PEB is the greater of Total Allocated BW or Total Power Equivalent BW (it's what the satellite operator will base the per Hz price on).

Scenario 1

10 Mbps Synchronous fixed Data Rate duplex – Determine the best overall modulation technique when considering: (1) synchronous data, (2) 99.95% link availability, and (3) Typical Ku-Band rain fade conditions.

System Configuration Information:

Satellite	Location	Beam	Txpdr Center Freq.	Station A Location	Station A Antenna	Station B Location	Station B Antenna
IS-1002	359 °E	312	13.955 / 12.705	Tripoli, Libya	7.8 m	Oran, Algeria	2.4 m

Scenario 1a: Conventional two (2) carrier link: No ACM Value

	Occupied BW [1]	Threshold Mod/Cod [2]	CnC Es/No Penalty [3]	Threshold Es/No Req.[4]	Clear Sky Es/No [5]	Link Margin [6]
Link A to B	7.06 MHz	8-PSK 3/5	0.0 dB	6.7 dB	11.1 dB	4.5 dB
Link B to A	7.06 MHz	8-PSK 3/5	0.0 dB	6.7 dB	11.1 dB	4.5 dB

Tot Alloc BW [7]	Tot PEB BW [8]	Clear Sky Mod/Cod A to B [9]	ACM Max DR A to B [10]	Clear Sky Mod/Cod B to A [11]	ACM Max DR B to A [12]	Total DR Increase % [13]
14.12 MHz	12.81 MHz	8-PSK 3/5	10.0 Mbps	8-PSK 3/5	10.0 Mbps	**0.0%**

Scenario 1b: Carrier in Carrier link: No ACM Value

	Occupied BW	Threshold Mod/Cod	CnC Es/No Penalty	Threshold Es/No Req.	Clear Sky Es/No	Link Margin
Link A to B	(9.52/2) MHz	QPSK 2/3	0.3 dB	4.0 dB	8.5 dB	4.5 dB
Link B to A	(9.52/2) MHz	QPSK 2/3	0.3 dB	4.0 dB	8.5 dB	4.5 dB

Tot Alloc BW	Tot PEB BW	Clear Sky Mod / Cod A to B	ACM Max DR A to B	Clear Sky Mod / Cod B to A	ACM Max DR B to A	Total ACM DR Increase %
9.52 MHz	9.25 MHz	QPSK 2/3	10.0 Mbps	QPSK 2/3	10.0 Mbps	**0.0%**

Scenario 1 Summary (% Improvement vs. Conventional Link)

[14]	Conventional Link	Conventional with ACM	CnC without ACM	CnC with ACM (Reduced BW)	CnC with ACM (Max Throughput)
BW / PEB	14.12 MHz	14.12 MHz (0.0%)	9.52 MHz (32.5%)	9.52 MHz (32.5%)	N/A
Guar. DR	20 Mbps	20 Mbps (0.0%)	20 Mbps (0.0%)	20 Mbps (0.0%)	N/A
Max DR	20 Mbps	20 Mbps (0.0%)	20 Mbps (0.0%)	20 Mbps (0.0%)	N/A

Scenario 1 exemplifies a conventional synchronous circuit. Synchronous circuits and synchronous data interfaces, such as G.703, RS422, and V.35, do not allow for variances in data rate once the circuit is established. They are static in throughput and have strict clocking and timing requirements. For this reason, a statistical and dynamic technology such as ACM cannot be used in these types of circuits and provides no value regardless of the available link margin.

As discussed earlier, Carrier-in-Carrier is a static technology that provides an unchanging advantage and proves to be of substantial value in synchronous circuits. As seen in the Scenario 1 summary section, CnC without ACM provides a 32.5% BW/PEB savings over a conventional link. In all other scenarios, the result is either unimproved or not applicable.

Financially Speaking: Assuming a cost per MHz of BW/PEB is $3000.00 USD per month, a service provider could save $975/MHz * (14.12 – 9.52) = $4,485 per month or $53,820 per year by deploying CnC on this circuit.

Scenario 2

Guaranteed minimum 10 Mbps SLA duplex link – Determine the best overall modulation technique when considering: (1) Asynchronous, packet-based Data, 2) Link 99.65% availability, and 3) Typical Ku-Band rain fade conditions.

System Configuration Information:

Satellite	Location	Beam	Txpdr Center Freq.	Station A Location	Station A Antenna	Station B Location	Station B Antenna
IS-1002	359 °E	312	13.955 / 12.705	Tripoli, Libya	7.8 m	Oran, Algeria	2.4 m

Scenario 2a: Conventional two (2) carrier link: Without and with ACM

	Occupied BW	Threshold Mod/Cod	CnC Es/No Penalty	Threshold Es/No Req.[1]	Clear Sky Es/No	Link Margin
Link A to B	5.64 MHz	8-PSK 3/4	0.0 dB	9.0 dB	10.6 dB	1.6 dB
Link B to A	4.76 MHz	16-APSK 2/3	0.0 dB	10.6 dB	12.1 dB	1.5 dB

Tot Alloc BW	Tot PEB BW	Clear Sky Mod / Cod A to B	ACM Max DR A to B	Clear Sky Mod / Cod B to A	ACM Max DR B to A	Total ACM DR increase %
10.40 MHz	9.84 MHz	16-APSK 2/3	11.8 Mbps	16-APSK 4/5	11.9 Mbps	**18.5%**

Scenario 2b: Carrier in Carrier link: Without and with ACM

	Occupied BW [2]	Threshold Mod/Cod	CnC Es/No Penalty	Threshold Es/No Req.	Clear Sky Es/No	Link Margin
Link A to B	(14.1/2) MHz	8-PSK 3/5	0.3 dB	6.9 dB	8.4 dB	1.5 dB
Link B to A	(14.1/2) MHz	8-PSK 3/5	0.3 dB	6.9 dB	8.4 dB	1.5 dB

Tot Alloc BW	Tot PEB BW	Clear Sky Mod / Cod A to B	ACM Max DR A to B	Clear Sky Mod / Cod B to A	ACM Max DR B to A	Total ACM DR increase %
7.05 MHz	6.62 MHz	8-PSK 2/3	11.1 Mbps	8-PSK 2/3	11.1 Mbps	**11.0%**

Scenario 2 Summary (% Improvement vs. Conventional Link)

	Convention Link	Conventional with ACM	CnC without ACM	CnC with ACM (Reduced BW)	CnC with ACM (Max Throughput)
BW / PEB	10.4 MHz	10.4 MHz (0.0%)	7.05 MHz (32.2%)	7.05 MHz (32.2%)	10.4 MHz (0.0%)
Guar. DR	20 Mbps	20 Mbps (0.0%)	20 Mbps (0.0%)	20 Mbps (0.0%)	29.5 Mbps (47.5%)
Max DR	20 Mbps	23.7 Mbps (18.5%)	20 Mbps (0.0%)	22.2 Mbps (11.0%)	32.7 Mbps (63.5%)

In Scenario 2, we can see that packet-based networks (when combined with ACM) can yield a higher data throughput. In this scenario, however, due to the 99.65% Link Availability chosen (vs. 99.85% in scenario 1), the link margin needed is only about 1.5 dB. Due to this lower link margin, we see only a minimal (18.5%) increase in data throughput due to ACM alone. As shown in the column CnC with ACM (Reduced BW), Carrier-in-Carrier offers a 32.2% savings in allocated bandwidth, plus an 11.0% increase in data throughput due to ACM.

Financially Speaking: Assuming a cost per MHz of BW/PEB is $3000.00 USD per month, a service provider could save $966/MHz * (10.4 – 7.05) = $3,236 per month or $38,833 per year by deploying CnC and would increase user throughput by an additional 2.2 Mbps for the majority of the year.

So, what happens if we convert the savings in bandwidth to additional throughput?

As seen in the CnC with ACM (Max Throughput) column of the Summary section, a user could choose to convert BW savings into additional throughput by running a 10.4 MHz CnC link (equivalent to the Scenario 2a Total allocated BW). Even in the most highly faded condition, running 8-PSK 3/5 Mod/Cod, CnC alone would give the user 29.5 Mbps of capacity (14.7 Mbps each way). This is a 47.5% increase over the 20 Mbps guaranteed SLA. CnC, without ACM, in a highly faded link condition provides a 29% throughput advantage over ACM in CLEAR SKY CONDITIONS!

When clear sky conditions do arise, CnC with ACM will run at Mod/Cod 8-PSK 2/3 offering 32.7 Mbps of capacity (16.3 Mbps each way). This is 63.5% over the contracted SLA figure of 20 Mbps and 45% better than ACM alone.

As we are running a BW limited link (being charged by BW not by PEB or power), we know that the cost per month for the CnC 10.4 MHz is the same as the Conventional (non CnC) 10.4 MHz and we have now increased our Data Rate capacity by up to 63.5% over our SLA.

When looking at all available options, it is clear that CnC combined with ACM provides the best overall result.

Scenario 3

Guaranteed minimum 10 Mbps SLA duplex link – Determining the best overall modulation technique when considering: 1) Asynchronous, packet-based, Data Link, 2) 99.7% availability, and 3) Ku-Band rain fade conditions in severe rain fade locations.

System Configuration Information:

Satellite	Location	Beam	Txpdr Center Freq.	Station A Location	Station A Antenna	Station B Location	Station B Antenna
IS-907	332.5 °E	71	14.0425 / 10.9925	Abidjan, Côte d'Ivoire	7.8 m	Lome, Togo	2.4 m

Scenario 3a: Conventional two (2) carrier link: Without and with ACM

	Occupied BW	Guaranteed Mod/Cod	CnC Es/No Penalty	Threshold Es/No Req.[1]	Clear Sky Es/No	Link Margin
Link A to B	6.35 MHz	8-PSK 2/3	0.0 dB	7.8 dB	15.9 dB	8.1 dB
Link B to A	4.23 MHz	16-APSK 3/4	0.0 dB	11.7 dB	18.6 dB	6.9 dB

Tot Alloc BW	Tot PEB BW	Clear Sky Mod / Cod A to B	ACM Max DR A to B	Clear Sky Mod / Cod B to A	ACM Max DR B to A	Total ACM DR increase %
10.58 MHz	10.15 MHz	32-APSK 5/6	20.8 Mbps	32-APSK 9/10	14.9 Mbps	**78.5%**

Scenario 3b: Carrier in Carrier link: Without and with ACM

	Occupied BW [2]	Threshold Mod/Cod	CnC Es/No Penalty	Threshold Es/No Req.	Clear Sky Es/No	Link Margin
Link A to B	(14.1/2) MHz	8-PSK 3/5	0.3 dB	6.9 dB	14.9 dB	8.0 dB
Link B to A	(14.1/2) MHz	8-PSK 3/5	0.3 dB	6.9 dB	13.8 dB	6.9 dB

Tot Alloc BW	Tot PEB BW	Clear Sky Mod / Cod A to B	ACM Max DR A to B	Clear Sky Mod / Cod B to A	ACM Max DR B to A	Total ACM DR increase %
7.05 MHz	**7.53 MHz**	32-APSK 3/4	20.8 Mbps	16-APSK 5/6	18.5 Mbps	**96.5%**

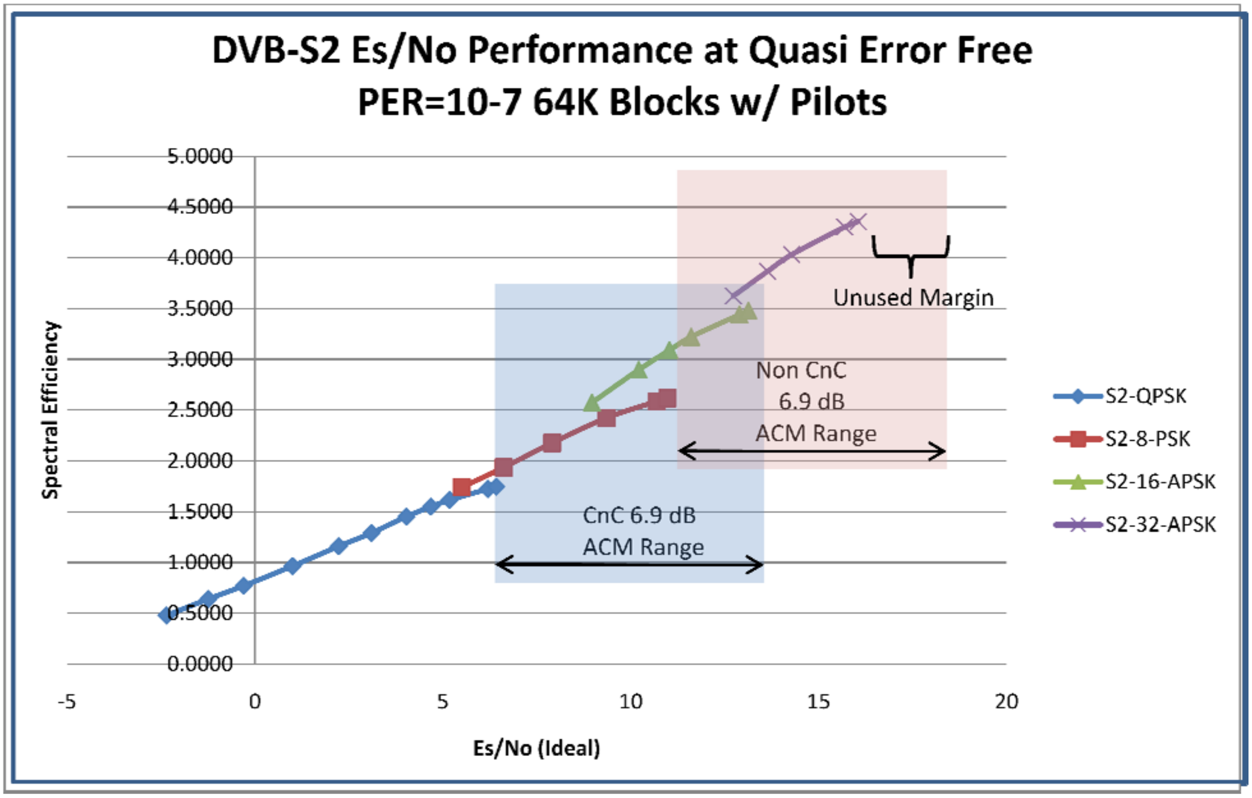
Scenario 3 Summary (% Improvement vs. Conventional Link)

	Conventional Link	Conventional with ACM	CnC without ACM	CnC with ACM (Reduced BW)	CnC with ACM (Max Throughput)
BW / PEB	10.58 MHz	10.58 MHz (0.0%)	7.53 MHz (28.8%)	7.53 MHz (28.8%)	9.90 MHz (0.0%)*
Guar. DR	20 Mbps	20.0 Mbps (0.0%)	20 Mbps (0.0%)	20 Mbps (0.0%)	28 Mbps (40.0%)
Max DR	20 Mbps	35.7 Mbps (78.5%)	20 Mbps (0.0%)	39.3 Mbps (96.5%)	55.1 Mbps (175%)

In Scenario 3 we see that packet-based networks running ACM can improve data throughput by a significant amount. In this scenario, a 99.7% Link Availability, Ku-Band operation, and a combination of geographical locations that experience severe fade conditions creates a Link Margin demand of 6.9 to 8.1 dB. Due to this high link margin, we see substantial (78.5%) increase in data throughput due to ACM alone.

Carrier in Carrier offers a 28.8% savings in allocated bandwidth combined with a 96.5% increase in data throughput due to ACM as seen in the CnC with ACM (Reduced BW) column. It can be seen that in this scenario the increase in data rate due to ACM was slightly higher in the CnC with ACM (Reduced BW) circuit than in the ACM only circuit (96.5% vs. 78.5%). The reason for this is quite simple. The Link margin of 6.9 dB (scenario 3a Link B to A) available in clear sky conditions far exceeded the most efficient Mod/Cod (32-APSK 9/10) Es/No requirement and, therefore, could not be further converted to increased capacity. This is another advantage of using CnC technology in combination with ACM. In virtually all CnC circuits a lower mod/cod can be used as we are spreading the signal, requiring a lower Es/No but over a larger occupied BW. As can be seen in the graph below, when you can attain your minimum SLA by using a mod/cod that requires a lower Es/No, more link margin can be converted to user throughput.

Furthermore, as you can see in the “Ideal” spectral efficiency vs. Es/No graph below, for every 5 dB of change in Es/No, there is roughly an increase of 1.6 to 1.8 times the spectral efficiency. Meaning, for every 5dB of link margin, in an ideal DVB-S2 implementation, throughput should increase by 60 to 80% regardless of where you begin (Threshold Es/No).



Financially Speaking: Assuming a cost per MHz of BW/PEB is $3000.00 USD per month, a service provider could save $864/MHz * (10.58 – 7.53) = $2,635 per month or $31,622 per year by deploying CnC and would increase user throughput by an additional 19.3 Mbps for the majority of the year.

As we have done in Scenario 2, let us see what happens if we convert the savings in bandwidth to additional throughput. In Scenario 3, the CnC link is power limited, running a 7.05 MHz carrier is equivalent to using 7.53 MHz PEB. For this reason, we need to compare a 9.9 MHz (Total Allocated BW) CnC link equating to a 10.58 MHz BW/PEB, as this will give us a realistic equivalent satellite cost.

As seen in the CnC with ACM (Max Throughput) column of the Summary section, a user could choose to convert BW savings into additional throughput by running a 9.9 MHz CnC link. In the most highly faded condition, running 8-PSK 3/5 Mod/Cod in both directions, CnC alone would give the user 28.0 Mbps of capacity (14.0 Mbps each way). This is a 40.0% increase over the 20 Mbps guaranteed SLA even in the most faded of conditions (where ACM will provide little to no value). When clear sky conditions do arise, CnC with ACM will run at Mod/Cod 32-APSK ¾ in one direction and 16-APSK 5/6 in the opposite direction offering 55.1 Mbps of capacity (29.2 Mbps A to B, 25.9 Mbps B to A). This is **175%** over the contracted SLA figure of 20 Mbps and 96.5% better than ACM alone.

Again, it is clear that DoubleTalk Carrier-in-Carrier combined with ACM provides the best overall result.

Scenario 4 (E3 Link Optimization)

E3 (34.368 Mbps) Synchronous fixed Data Rate duplex – Determine the best overall modulation technique when considering: (1) synchronous 34.368 Mbps E3 data, (2) 99.95% link availability, and (3) Typical Ku-Band rain fade conditions.

System Configuration Information:

Satellite	Location	Beam	Txpdr Center Freq.	Station A Location	Station A Antenna	Station B Location	Station B Antenna
IS-1002	359 °E	312	13.955 / 12.705	Tripoli, Libya	7.8 m	Oran, Algeria	2.4 m

Scenario 4a (E3): Conventional two (2) carrier link: No ACM Value

	Occupied BW	Threshold Mod/Cod	CnC Es/No Penalty	Threshold Es/No Req.	Clear Sky Es/No	Link Margin
Link A to B	24.25 MHz	8-PSK 3/5	0.0 dB	6.7 dB	11.1 dB	4.5 dB
Link B to A	24.25 MHz	8-PSK 3/5	0.0 dB	6.7 dB	11.1 dB	4.5 dB

Tot Alloc BW	Tot PEB BW	Clear Sky Mod/Cod A to B	ACM Max DR A to B	Clear Sky Mod/Cod B to A	ACM Max DR B to A	Total DR Increase %
48.50 MHz	44.03 MHz	8-PSK 3/5	34.368 Mbps	8-PSK 3/5	34.368 Mbps	**0.0%**

Scenario 4b (E3): Carrier in Carrier link: No ACM Value

	Occupied BW	Threshold Mod/Cod	CnC Es/No Penalty	Threshold Es/No Req.	Clear Sky Es/No	Link Margin
Link A to B	(65.47/2) MHz	QPSK 2/3	0.3 dB	4.0 dB	8.5 dB	4.5 dB
Link B to A	(65.47/2) MHz	QPSK 2/3	0.3 dB	4.0 dB	8.5 dB	4.5 dB

Tot Alloc BW	Tot PEB BW	Clear Sky Mod / Cod A to B	ACM Max DR A to B	Clear Sky Mod / Cod B to A	ACM Max DR B to A	Total ACM DR Increase %
32.73 MHz	31.80 MHz	QPSK 2/3	34.368 Mbps	QPSK 2/3	34.368 Mbps	**0.0%**

Scenario 4 (E3) Summary (% Improvement vs. Conventional Link)

	Conventional Link	Conventional with ACM	CnC without ACM	CnC with ACM (Reduced BW)	CnC with ACM (Max Throughput)
BW / PEB	48.50 MHz	48.50 MHz (0.0%)	32.73 MHz (32.5%)	32.73 MHz (32.5%)	N/A
Guar. DR	34.368 Mbps	34.368 Mbps (0.0%)	34.368 Mbps (0.0%)	34.368 Mbps (0.0%)	N/A
Max DR	34.368 Mbps	34.368 Mbps (0.0%)	34.368 Mbps (0.0%)	34.368 Mbps (0.0%)	N/A

Scenario 4, as with scenario 1, exemplifies a conventional synchronous circuit. E3 circuits and synchronous data interfaces, such as G.703 do not allow for variances in data rate once the circuit is established. They are static in throughput and have strict clocking and timing requirements. For this reason, a statistical and dynamic technology such as ACM cannot be used in these types of circuits and provides no value regardless of the available link margin.

Carrier-in-Carrier's static benefit provides an unchanging advantage and proves to be of substantial value in E3 circuits. As seen in the Scenario 4 summary section, CnC without ACM provides a 32.5% BW/PEB savings over a conventional link. In all other scenarios, the result is either unimproved or not applicable.

Financially Speaking: Assuming a cost per MHz of BW/PEB is $3000.00 USD per month, a service provider could save $975/MHz * (48.50 – 32.73) = $15,375 per month or $184,500 per year by deploying CnC on this circuit.

Conclusion

When considering bandwidth conservation, user data throughput maximization or a combination of the two, there are many choices and technologies available. Synchronous circuits greatly benefit by using Carrier-in-Carrier's definitive and static BW/PEB savings, and cannot benefit through the use of ACM. Non Synchronous, packet-based circuits can be improved by ACM, but these improvements are even more substantial when a combination of ACM and Carrier-in-Carrier technologies are deployed.

Comtech EF Data has a team of sales engineering personnel who can help analyze the benefits of using these advanced technologies on your existing or newly provisioned links. Please contact us for more information.

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