DoubleTalk™ Carrier-in-Carrier™

Bandwidth Compression Providing Significant Improvements in Satellite Bandwidth Utilization

September 27, 2004

1 Introduction

Space segment costs are typically the most significant operating expense for any satellite-based service, having a direct impact on the viability and profitability of the service. Satellite transponder costs are determined by occupied bandwidth, as well as power used. For optimal results, a satellite circuit should use similar share of transponder bandwidth and power.

Traditionally, this has involved trade-offs between modulation and coding, once the satellite and earth station parameters are fixed. The newer Forward Error Correction (FEC) schemes, such as Turbo product Codes (TPC) and now the Low-Density Parity-Check Codes (LDPC) can provide increased link reliability while requiring less power compared to older schemes, such as Viterbi Reed Solomon and 8-PSK Pragmatic Trellis Coded Modulation with Reed Solomon (IESS-310). Conversely, higher order modulation schemes can increase data throughput without increasing the bandwidth, but at a significant increase in power.

Another consideration is antenna size. Larger antennas with increased gain require less power. However, it is not always feasible to use the largest available antenna, thereby increasing the power budget.

Of late, the newer satellites have had more power available, whereas the older satellite were generally power limited. In conjunction with newer FECs, this has caused greater imbalance in transponder bandwidth and power utilization, leaving excess power with very few means to profitably utilize it.[1]

Now, Comtech EF Data, in partnership with Applied Signal Technology, Inc., adds a new dimension to satellite bandwidth optimization – DoubleTalk™ Carrier-in-Carrier™. This innovative technology, provides a significant improvement in bandwidth utilization, beyond what is possible with FEC and modulation alone, allowing users to either reduce operating expenses or increase throughput.

2 DoubleTalk Carrier-in-Carrier

Designed for bandwidth compression, Carrier-in-Carrier is based on Applied Signal Technology's DoubleTalk, which uses "Adaptive Cancellation," a patent pending technology that allows full duplex satellite links to transmit concurrently in the same segment of transponder bandwidth. The result is reducing the occupied bandwidth by up to 50% depending on the initial link configuration. Again, depending on the link, there may be an insignificant increase in the transmitted power and surprisingly, in many instances it may even lead to a reduction in transmitted power (by allowing a more power efficient modulation and FEC combination).

The following figures illustrate the process for a full duplex link:

[1] The transponder power utilization can be artificially reduced by lowering the antenna size, however it would be of little help in increasing the data throughput in a bandwidth limited satellite.

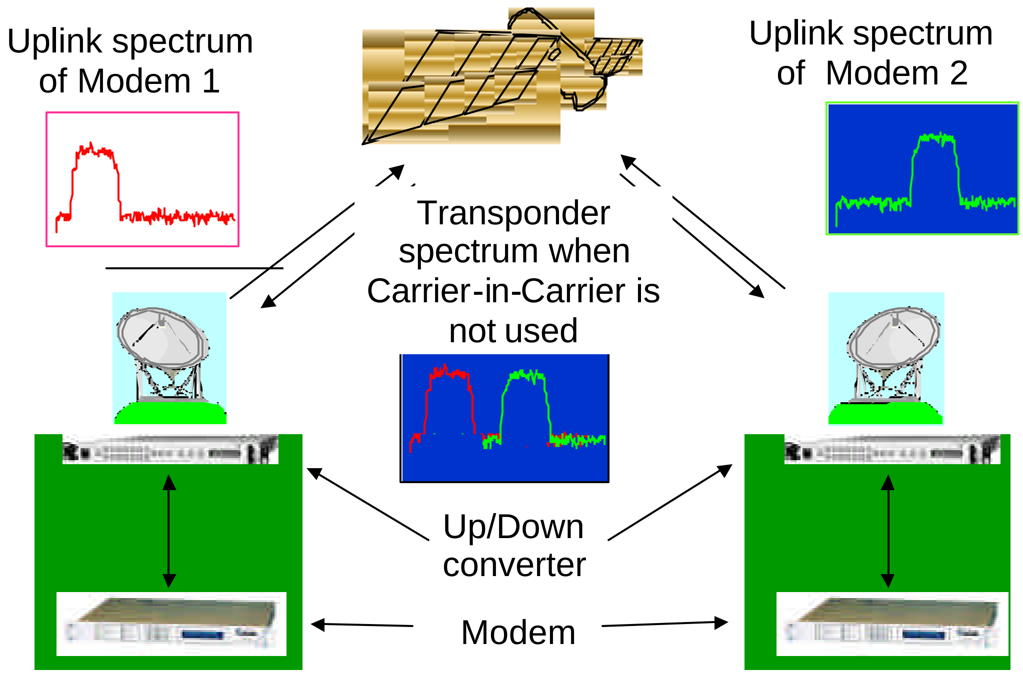

Figure 1. Full Duplex Link Before DoubleTalk Carrier-in-Carrier

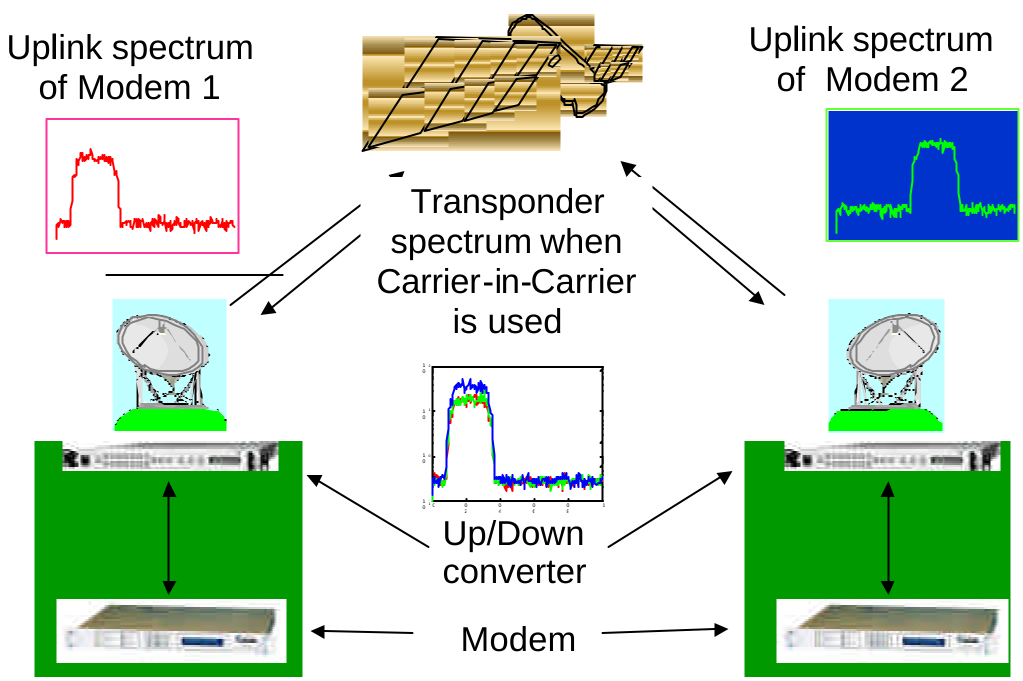

Figure 2. Full Duplex Link with DoubleTalk Carrier-in-Carrier

Figure 1 illustrates a conventional full duplex links, where the forward and return signals are transmitted on different carrier frequencies such that they occupy different positions on the transponder.

Figure 2 illustrates the configuration where DoubleTalk Carrier-in-Carrier is used. The forward and return signals are transmitted on the same carrier frequencies, occupying the same position on the transponder. The transponder then downlinks the composite signal. The DoubleTalk Carrier-in-Carrier function separates the intended signal from the composite signal and sends it for further processing.

Use of DoubleTalk Carrier-in-Carrier results in negligible degradation of the signal C/N (typical Eb/No degradation of less than 0.5 dB compared to non DoubleTalk Carrier-in-Carrier operation). Furthermore, the total transmit power utilization (before and after) at the transponder may increase marginally or may even decrease if a different modulation and coding is used for optimizing the link.

In some scenarios, the forward and return signals may not be at the same power level because of different coding, modulation or antenna sizes at the earth stations. DoubleTalk Carrier-in-Carrier still performs even when signals differ by as much as 10 dB, well within the power disparity of most links. Higher power imbalance would most likely cause degradation in performance depending on the modulation and the C/N.

2.1 DoubleTalk Carrier-in-Carrier Cancellation Process

DoubleTalk Carrier-in-Carrier achieves state-of-the-art performance by combining the latest Field Programmable Gate Array (FPGA) and signal processing technology. The cancellation process includes delay and frequency estimation and tracking, adaptive filtering, and coherent combining. It continually estimates and tracks all parametric differences between the local uplink signal and its image within the downlink. Through proprietary adaptive filtering and phase locked loop implementations, it dynamically compensates for these differences by appropriately adjusting the delay, frequency, phase and amplitude of the sampled uplink signal, resulting in excellent cancellation performance of about 30 dB.

When a full duplex satellite connection is established between two sites, separate satellite channels are allocated for each direction. If both directions transmitted on the same channel, each side would normally find it impossible to extract the desired signal from the aggregate due to interference originating from its local modulator. However since this interference is produced locally, it is possible to estimate and remove its influence prior to demodulation of the data transmitted from the remote location.

Taking the modulator output, delaying it to match the round trip delay and using an adaptive filter to cancel an estimate of the local component from the aggregate signal accomplishes the cancellation.

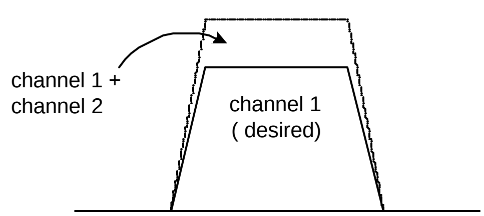

Figure 3 - Resultant Spectrum after Cancellation

For the DoubleTalk Carrier-in-Carrier function, it is necessary to provide each demodulator with a copy of its local modulator's output. Figure 4 shows the topology of a full duplex communication link between two locations, showing the additional modulator to demodulator data paths.

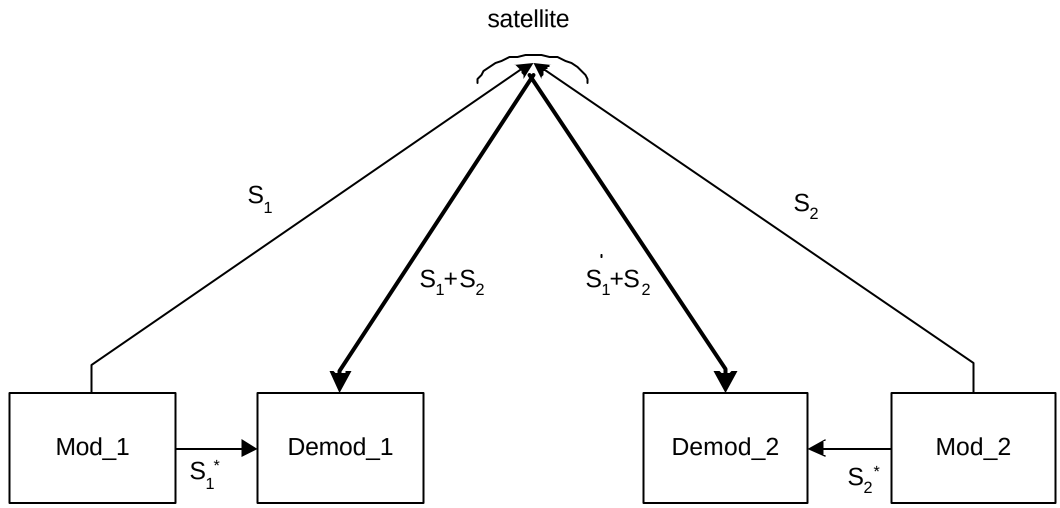

Figure 4 - Full Duplex Topology with DoubleTalk Carrier-in-Carrier

DoubleTalk Carrier-in-Carrier process consists of two major steps:

- An initial estimation of the round trip delay, and
- Signal cancellation

For round trip delay estimation, a search algorithm is utilized that correlates the received satellite signal to a stored copy of the local modulator's transmitted signal. It varies the delay and frequency offset of the modulator's local copy and correlates it with the down-converted IF signal, finding the exact round trip delay.

For signal cancellation, the input delay is set to the value derived from the initial estimation process. An interference canceller takes this delayed data and the down-converted IF signal and performs the cancellation, thereby extracting the desired signal. The interference canceller uses an adaptive equalizer (adaptive filter) to create an estimate of the interfering signal and subtracts this estimate from the aggregate signal. The remaining signal is the desired signal and can now be successfully demodulated.

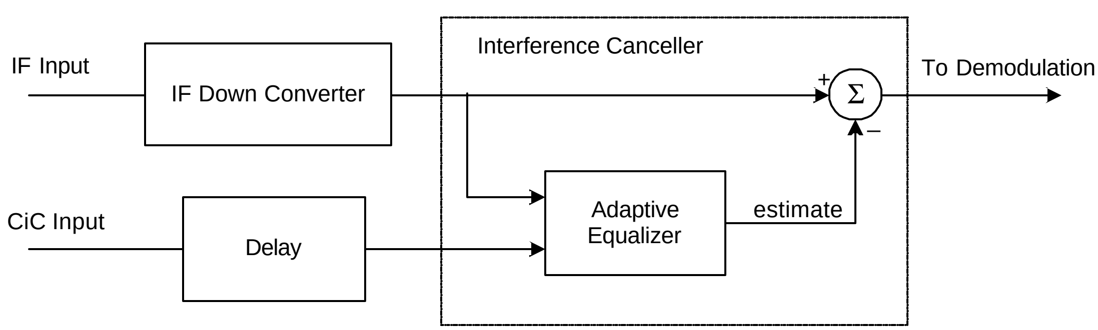

Figure 5. Cancellation Process Block Diagram

3 Operational Savings

The CDM-Qx is the first Comtech EF Data modem to incorporate the powerful DoubleTalk Carrier-in-Carrier functionality.

The following charts compare DoubleTalk Carrier-in-Carrier bandwidth utilization for a full duplex E1 (2.048 Mbps) over a range of antenna size, with the best of[2]:

- Viterbi Reed Solomon
- 8-PSK/TCM/RS (IESS-310)
- Turbo Product Code
- Low-Density Parity-Check Codes

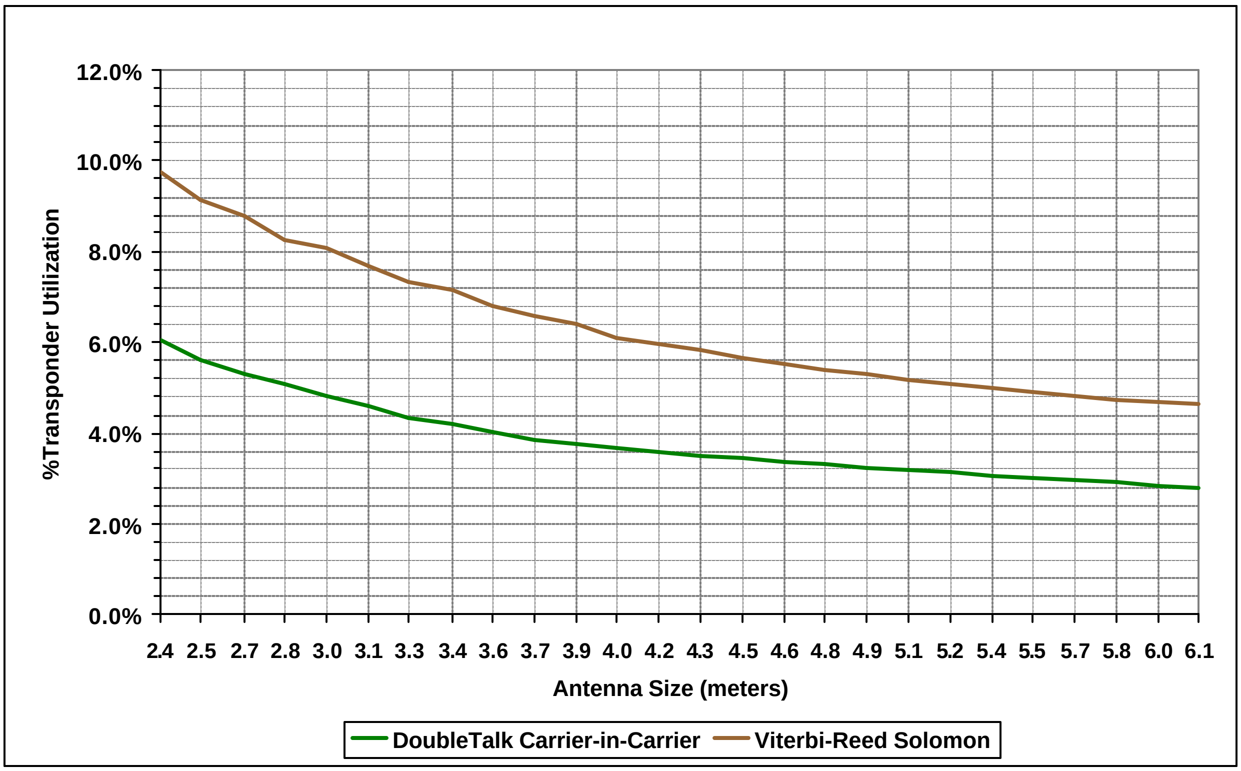

Figure 6. DoubleTalk Carrier-in-Carrier vs. Viterbi Reed-Solomon

[2] Eb/No performance for FEC and modulation types supported by Comtech EF Data's CDM-600 were used to find the best Viterbi-Reed Solomon, 8PSK/TCM/RS, TPC and LDPC combination for the given satellite and earth station parameters and compared with CDM-Qx using DoubleTalk Carrier-in-Carrier and TPC.

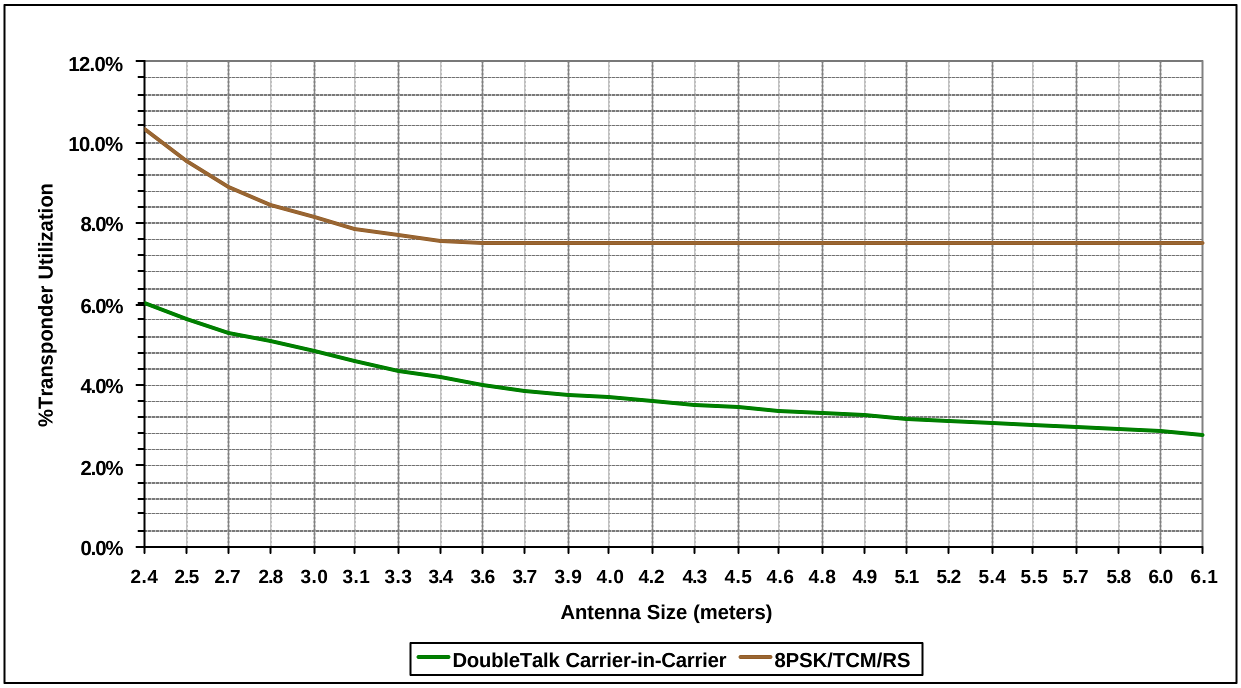

Figure 7. DoubleTalk Carrier-in-Carrier vs. 8-PSK/TCM/RS (IESS-310)

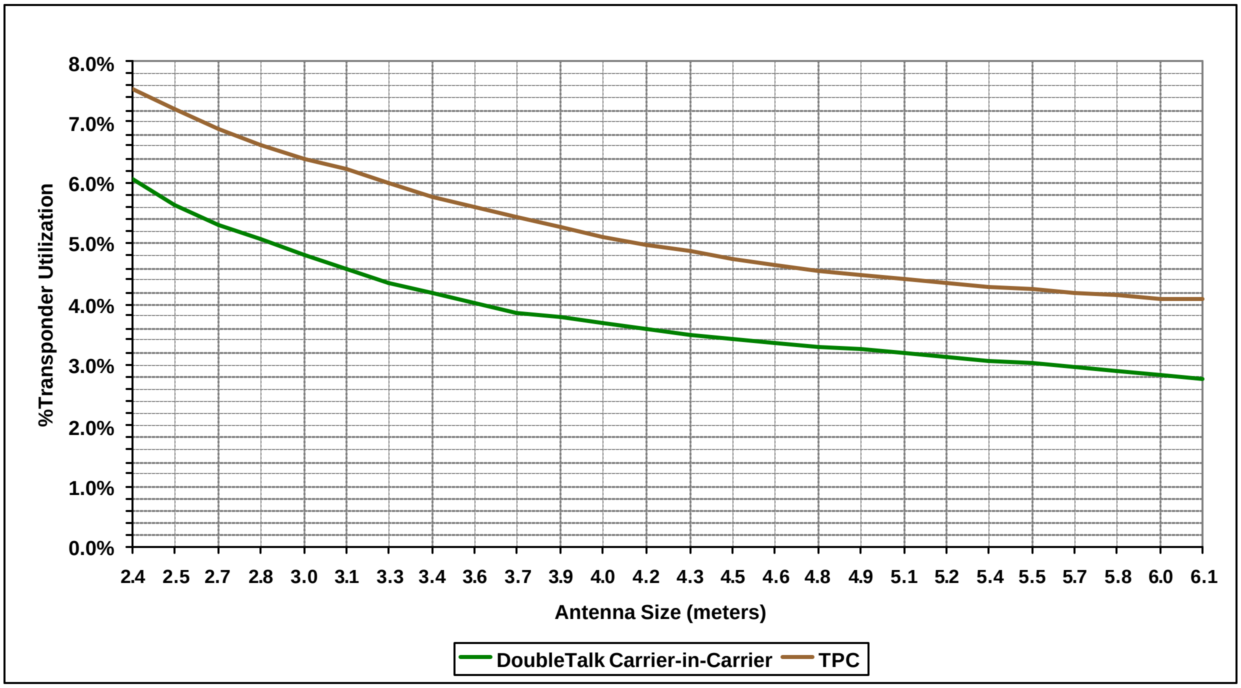

Figure 8. DoubleTalk Carrier-in-Carrier vs. TPC

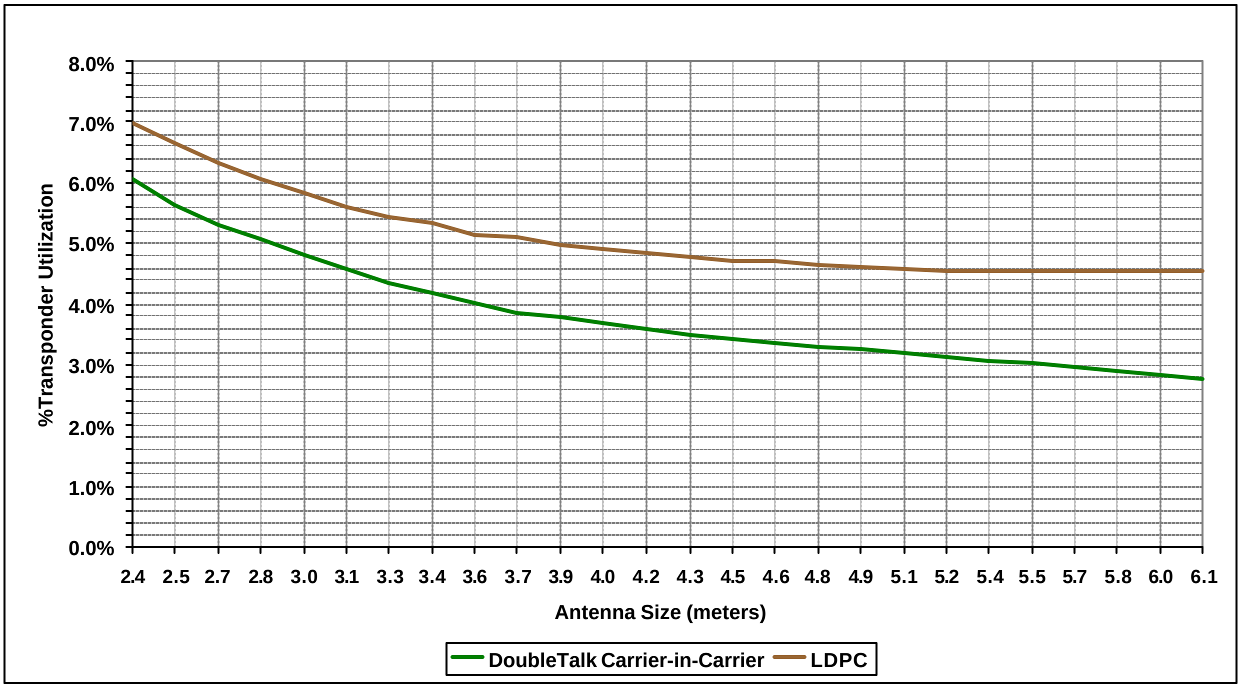

Figure 9. DoubleTalk Carrier-in-Carrier vs. LDPC

For all the charts, the satellite (typical C-band) and other earth station parameters (except for Antenna size) are fixed.

The average savings over all antenna sizes, in this particular case, when using DoubleTalk Carrier-in-Carrier were:

- 39.5% over Viterbi-Reed Solomon
- 51.5% over 8-PSK/TCM/RS
- 27.2% over TPC
- 26% over LDPC

Depending on the transponder leasing cost, return on investment for the CDM-Qx with the DoubleTalk Carrier-in-Carrier option would be within a few months.

4 Summary

Comtech EF Data's DoubleTalk Carrier-in-Carrier can provide significant savings in operational expenses.

The following should be considered when evaluating DoubleTalk Carrier-in-Carrier:

- DoubleTalk Carrier-in-Carrier can only be used for full duplex links where the transmitting earth station is able to receive itself.
- DoubleTalk Carrier-in-Carrier can be used in both bandwidth limited and power limited situations
  - ➢ For DoubleTalk Carrier-in-Carrier to provide savings in a power limited case, the original link is either using a non-TPC FEC or if using TPC has a spectral efficiency of at least 1.5 bits/Hz or better, i.e. QPSK, R=3/4 TPC or better
- The maximum savings is generally achieved when the original link is symmetric

Please contact Comtech EF Data Sales for more information about this innovative technology.

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